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THE FIRST MANNED SPACE FLIGHT

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 2, Mar-Apr 81 pp 5-7

[Article by O. G. Gazenko, A. M. Genin, N. N. Gurovskiy and A. R. Kotovskaya, submitted 30 Oct 80]

[Text] The development of rocket technology in the middle of our century provided the technical possibilities for realizing the most fantastic idea nurtured by mankind for centuries, that of a man flying in space.

As soon as a manned space flight became a real scientific and technological task, a program for fulfilling it began to be systematically worked on. There were many aspects to this program. It was based on the hypothesis that it is possible in principle, for man to live and be active during a space flight.

This hypothesis, which was expounded already by K. E. Tsiolkovskiy, appeared quite plausible at that time, and it was shared by most specialists in aviation medicine. However, one also had to take into consideration other ideas, which were often voiced in scientific and popular publications. These ideas were based on general biological considerations to the effect that the space environment (and primarily weightlessness) was hostile to all living things, since the entire animal and plant kingdom had been formed in a gravity field.

Each of the hypotheses had to be confirmed experimentally; for this reason, in the early 1950's, systematic experimental research on the biological effects of weightlessness was started in our country, at the initiative of Academician S. P. Korolev.

Experiments were conducted with vertical launching of scientific research rockets that reached altitudes of 100-200-450 km. Dogs, rats and mice were the objects of this research. During these flights, a state of weightlessness lasted only a few minutes; however, if this factor had a deleterious effect on highly organized organisms, this would have been sufficient time to discover changes in the animals' behavior and physiological reactions.

The series of experiments with vertically launched rockets end with the launching of the second artificial satellite of earth, with the dog, Layka, on board, and this time weightlessness lasted for a longer period.

This series of studies yielded unequivocal results in favor of the hypothesis that man could perform an orbital space flight, and it served as an impetus for development of the entire program.

In this connection, a series of studies was begun in 1956 to determine the permissible levels of factors related to the dynamics of space flights (accelerations during lift-off and descent, vibration) and man's living conditions in a pressurized cabin entirely isolated from the external environment (total pressure and partial pressure of gases contained in the artificial atmosphere, temperature, noise, illumination, etc.).

Concurrently, work began on development of protection against the deleterious effects of space flight factors, particularly with regard to emergency situations.

The problem of the effect on man of cosmic radiation required much attention. Although it was known that when manned flights went beyond the radiation belts of earth the estimated radiation dosage was low, the biological effects of heavy particles of galactic radiation remained unclear. The quite probable solar bursts, which are associated with powerful flux of charged particles also presented a serious danger.

In view of the fact that the experiments with animals in space flight had still been brief, and there was no certainty as to the validity of extrapolating (in this situation) these results to man, as well as in view of the uncertainty as to degree of risk related to cosmic radiation, the main strategy of manned space flights was to gradually extend, from mission to mission, the time spent in orbit aboard an artificial earth satellite. Of course, this approach implied preparation of both man and spacecraft for maximum flight time. This time also conformed with the serious emergency situation discussed at that time, failure of the retrorocket. In the event of such a situation, the spacecraft could remain in orbit up to 12 days, while the descent had to be performed by means of braking in the upper layers of the atmosphere, and it would inevitably be associated with heating of the cowling and elevation of air temperature in the cabin.

All this made it quite difficult to choose the principles for construction and specific technical execution of life support and emergency rescue systems for cosmonauts.

Work dealing with definition of medical standards and development of methods to implement them proceeded concurrently, with the close collaboration of physicians, physiologists and hygienists with engineers who developed spacecraft, life support and rescue systems. Only such collaboration made it possible to solve the submitted problems rapidly and effectively. The permissible range of exposure of man to some factor was often determined on mock-ups of specific products, or simultaneously with functional tests of these products, with adjustment and refinement thereof. The entire construction of the spacecraft and its systems was corrected on the basis of the results of physiological studies. Not infrequently, future cosmonauts undergoing training for space flights were directly involved in these studies.

Screening of candidates for cosmonauts began in 1959. It was logical to decide to select the first cosmonauts among fighter pilots.

This decision was based on the fact that fighter pilots constitute a group that was specially screened among healthy people with good physical and mental development. Regular medical supervision was instituted for them. The profession of a pilot provided the knowledge needed in a cosmonaut, as well as skills and psychological traits, and it was similar to cosmonauts with regard to factors to which the men would be exposed. The examination and medical screening of cosmonauts were performed in stages. As a result, 20 people were selected out of several hundred candidates, and they made up the first group of cosmonauts.

The training of the cosmonauts for the first flight took into consideration analysis of the effects of space flight factors on man and the results of biomedical studies conducted aboard the satellite spacecraft returned to earth.

Development of the methods of preparing and training cosmonauts proceeded from the knowhow of aviation medicine. However, this knowhow was obviously insufficient as it applied to space flights. There were no ready systems or methods for training the first cosmonauts.

The main principles, upon which the training program was based, were to enhance the body's resistance to space flight factors, develop the necessary work skills and theoretical training.

The special training of the first group of cosmonauts took into consideration factors related to the dynamics of the flight (noise, vibration, accelerations, weightlessness), as well as the presence of cosmonauts in the spacecraft cabin (microclimate, isolation in a small area with severe restriction of movement, distinctive food, clothing, nervous and mental stress, etc.).

Special tests, laboratory research and cosmonaut training were motivated by the possibility of high temperatures in emergency situations.

The psychological distinctions of a space flight and the nature of work of the first cosmonaut had independent significance, from the standpoint of effects on man.

The novelty and uniqueness of the situation, the enormous responsibility for one's actions, in which mistakes were inadmisslbe--all this created significant nervous and mental tension [stress], and presented particularly great demands on the first cosmonaut's nervous system and mind. For this reason, to assure psychological reliability of the cosmonaut during the flight, there were special studies aimed at demonstration of the distinctions referable to the neuropsychological system of the cosmonaut.

The training included the following parts: orientation and training flights on aircraft equipped to reproduce weightlessness, long-term stays in specially equipped anechoic chambers, training on a centrifuge and vibration table, parachute training, and training in a mock-up of the Vostok spacecraft.

In the course of cosmonaut training, the candidates for the first manned space flight were identified. They were Yu. A. Gagarin and G. S. Titov. Many considerations, and not only medical ones, served as the basis for this choice. However, from the standpoint of health status and psychophysiological traits, both candidates were impeccable.

In the spring of 1961, in laboratories and plant shops tests were being completed and the final touches put on the first manned Vostok spacecraft; test launching of prototypes of these spacecraft was conducted with animals on board; the cosmonauts were going through the last of the training, while the technical management and state commission returned again and again to discussion of measures to assure the safety of the flight under any conceivable emergency situations. The reliability of each part of the spacecraft was again analzyed and, of course, the question of man's endurance of weightlessness and cosmic radiation was reviewed many times.

By this time, considerable experience had been gained from the flights of animals in rockets and artificial earth satellites; the cosmonauts' endurance of all reproduced space factors had been tested under laboratory conditions; theoretical conceptions about the possible mechanisms of action of weightlessness and cosmic radiation on man had emerged. All this made it possible to predict that cosmonauts would tolerate well a brief space flight. Specialists anticipated the possibility of development of vestibulovegetative disorders in weightlessness; however, it was obvious that they could not lead to impairment of health or loss of work fitness during a brief flight.

The world's first manned spacecraft was launched on 12 April 1961. The Soviet cosmonaut, Yu. A. Gagarin, was on board. The first flight was brief, lasting only 1.5 hours; however, the good condition of the returning cosmonaut, his high efficiency during the flight and after landing strengthened confidence in the possibility of advancement toward prolonging man's fruitful activity in space.

SURVEYS

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BIOMEDICAL TRAINING OF COSMONAUTS (HISTORY, CONTENT, STAGES, EVOLUTION AND TRENDS OF DEVELOPMENT)

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 2, Mar-Apr 81 pp 8-14

[Article by G. F. Khlebnikov, submitted 30 Oct 80]

[English abstract from source] On the basis of the Soviet literature changes in the biomedical training of cosmonauts are discussed and the major tendencies of its improvement are described.

[Text] In the last decades, science and technology have reached unprecedented heights, having opened to mankind the endless possibilities of learning the laws of the world around us.

Man's penetration into space is a vivid example of the advances of science. The days of 4 October 1957 and 12 April 1961 were the days on which these advances became a reality. The first landmarks on the road of development of cosmonautics were the launching of the first artificial satellite of earth (ASE) and the orbital flight of Yu. A. Gagarin.

From the very beginning, it became apparent that penetration into space and possibility of learning the laws of nature are linked with new and rather complex problems, unknown or little-known to science.

During the period preceding the first manned space flight, some scientists voiced their fear that even brief orbital flights could impair the psychophysiological condition and fitness of cosmonauts. The scientists were mindful of the presence of factors of the unknown, some degree of risk, as well as some dissatisfaction with the results of model experiments with animals [1-4].

As a result of the experimental studies conducted in the Soviet Union with animals flown aboard rockets and ASE's, aviation and space medicine scientists--V. I. Yazdovskiy, A. M. Genin, O. G. Gazenko, N. N. Gurovskiy, M. D. Yemel'yanov, A. R. Kotovskaya, I. I. Kas'yan, A. F. Seryapin, Ye. Ya. Shepelev--and many others obtained unique data in 1959-1961 concerning the possibility of animals' existence under space flight conditions [1, 5-8].

The main space flight factors that effect the human body were formulated [9, 10] on the basis of these data and the results of laboratory research, while N. N. Gurovskiy, F. D. Gorbov and Ye. A. Karpov developed the principles for preparing man for space flights. The proposed system was subsequently named biomedical training (BMT) [11-13].

Without discussing technical and other problems of training cosmonauts, we shall only deal with training of man as a biological object.

For man, unlike animals, not only to "survive," but to be an active "instrument" capable of receiving, analyzing, accumulating and, if necessary, transmitting to earth large amounts of diverse information [4, 14, 15], he must be trained, not only as a specialist-operator who must control the spacecraft systems [16], but as a biological object characterized by individual psychophysiological distinctions and capabilities [12]. Such preparation is needed primarily so that man can withstand the harmful effects of deleterious space flight factors, retaining normal fitness, as well as analyze and summarize information about the flight, actively affect its dynamics and make decisions that conform with the situation [12, 16, 17].

The effectiveness of BMT is determined by the cosmonaut's fitness and quality of his performance in flight [4, 12, 13, 16, 17].

The time required for BMT is determined primarily by the initial level of physical and functional state of the human body and its physiological capabilities [13, 18].

MBT consists of a set of specific and nonspecific elements of a research, testing and training nature, with constant medical monitoring of physiological parameters and changes therein in the course of the above elements.

BMT provides for demonstration of individual reactions of the body to deleterious space flight factors [9, 19-25], increasing the body's resistance to extreme flight factors, teaching cosmonauts how to use life support equipment and, if necessary, to render self-help and mutual help [26-29], as well as obtaining data needed to appoint candidates as crew members.

The resistance of the body is enhanced by using the different physical factors of space flights simulated under laboratory conditions, as well as extensive use of the ways and means of physical training, as well as adaptogens, stimulants, etc., if necessary.

Prior to preparations for the first manned space flight, which was based solely on the experience of aviation flights and experimental flights of animals aboard rockets and ASE, it was necessarv to define the requirements with regard to the cosmonaut's health status, to screen individuals that would be capable of making a space flight on the basis of their healthy status and physical qualities [9, 10, 30].

All of the cosmonauts, starting with Yu. A. Gagarin and ending with the members of the most recent international crews, observed that preparation of the human body is quite important for successful performance of flight missions. Initially, the word combination, "preparation [or training] of cosmonauts," sounded mostly medical. BMT took up over half the total time spent on training as a whole. At the present time, cosmonaut training is characterized by an extremely complex set of diversely directed measures, on the one hand, and some qualitative and quantitative change in nature of BMT, on the other.

Prior to the first manned space flights, there was no concept of "preparing man" in the broad functional and biological sense in industrial physiology or clinical medicine. As a rule, it dealt with minimal correction of health status within a relatively short time (segments), for example, preparation for testing or examining the effect of some physical factor.

The problem of preparing man for the world's first flight into space made it necessary to study the effects on man of a number of physical factors [9, 10, 30], including some that had been little-studied and difficult to reproduce on earth, but which had an adverse effect on cosmonauts in flight [22, 23, 25].

Soviet scientists--O. G. Gazenko, N. N. Gurovskiy, A. M. Genin, P. K. Isakov, S. A. Gozulov, F. V. Vasil'yev, Ye. M. Yuganov, V. I. Yazdovskiy, A. S. Barer, A. R. Kotovskaya, P. M. Suvorov, I. I. Bryanov, A. N. Babiychuk, N. M. Rudnyy, Y .. Karpov and others--made a worthy contribution to the inception of space medicine on the basis of human performance under unusual conditions, data about which were accumulated in aviation medicine and industrial physiology. They undertook a number of studies and very speedily obtained data that made it possible to preserve the fitness and health of cosmonauts, to obtain information about their physical condition while training on various stands and, mainly, during exposure to the deleterious space flight factors: transverse accelerations [19-21], brief weightlessness [22], vestibular stimuli [24, 25], neuroemotional tension [or stress] related to isolation [3, 4], hyperthermia, vibration [8] and others.

The medical objective of the series of short-term flights of cosmonauts aboard the Vostok satellite spacecraft consisted mainly of proving that it was basically possible for man to perform orbital flights [2].

At this stage of support of space flights, BMT included screening of physically strong and psychologically stable pilots capable of satisfactorily withstanding the effects of "standard" accelerations that occur when a spacecraft is inserted in orbit and when it descends to earth, weightlessness, vestibular stimuli reproduced on special stands, hyperthermia in a heat chamber, neuropsychological stability in an anechoic chamber.

Biomedical preparation of cosmonauts included the following: rotation on a centrifuge with reproduction of "standard" transverse G forces [20]; exposure to low atmospheric pressure and hypoxia in a pressure chamber; flights aboard aircraft with creation of brief weightlessness and parachute jumps [23]; exposure to high temperatures in a heat chamber; vestibular stimulation on special stands [24, 25]; testing neuropsychological stability during prolonged isolation [3, 4]; general physical and special-purpose physical training [13, 18]; study of theoretical bases of human anatomy and physiology, aviation and space medicine.

Subsequent space flights were characterized by systematic increase in duration and complexity of space flight programs. While the flight of Yu. A. Gagarin (Vostok-1) lasted 108 min, that of G. S. Titov (Vostok-2) lasted 25 h 11 min, A. G. Nikolayev (Vostok-3)--94 h, P. R. Popovich (Vostok-4)--70 h 42 min, V. F. Bykovskiy (Vostok-5))--119 h and V. V. Tereshkova (Vostok-6)--over 70 h.

The experience of these manned space flights revealed that cosmonauts encounter a set of deleterious factors and unusual living conditions in the cabin, they experience considerable neuropsychological stress, etc. To overcome these extreme factors, which are associated with stress, it is necessary to mobilize the mental and physical resources of the body, the cosmonauts must have a high degree of professional fitness, which is needed for good performance of the various operations related to control of spacecraft systems, upon which depends the safety of a space mission [2, 20, 21, 24, 25].

With reference to some aspects of MBT of a cosmonaut, we should mention several of the difficulties that are encountered. For example, simulation of weightlessness aboard aircraft is limited to only brief (up to 20-25 s) reproduction thereof. Obviously, it was not possible to familiarize the cosmonauts entirely with all aspects of the effect of this factor on the body, let alone predict the nature of a cosmonaut's reactions in a real space flight. As a result of analyzing the reactions of cosmonaut G. S. Titov, the hypothesis was expounded that weightlessness has a specific effect on the vestibular system [24, 25], and a system was developed for vestibular conditioning of cosmonauts with the use of passive and active methods.

The possibility of increasing resistance to accelerations was explored in order to condition cosmonauts to the transverse G forces inherent in orbit insertion of the spacecraft and descent to earth. Along with specific methods (rotation on a centrifuge), nonspecific ones were used, in particular, special physical exercises.

The results of the clinicophysiological examination (CPE) of cosmonauts, performed before and after space flights, confirmed the validity of the methods that were selected for preparing the body for a flight. The functional changes in the cardiovascular system, diminished endurance of physical loads and vestibular disorders found in some cosmonauts after the flights served as grounds for further refinement of the BMT system [30].

The next stages of development of cosmonauts were development of the Voskhod spacecraft and flights aboard these space flight vehicles. At this stage there was refinement of methods and means of controlling spacecraft, cosmonauts engaged in extravehicular activity, and other scientific and technological tasks were performed.

At the stage of the flights aboard the Voskhod series spacecraft, the problems related to extravehicular activity, man's movement and orientation in unsupported space, return into the spacecraft complicated significantly the tasks of cosmonaut training in general and BMT in particular. It became necessary to use new methods for assuring life in space (use of special suits, oxygen gear and others). It is expressly at this stage that the TU-104 aircraft-laboratories began to be used to create brief weightlessness and, unlike fighter aircraft, they mede it possible to refine elements of unsupported movement and other operations related to the cosmonauts' professional activities. Subsequently, this type of training became traditional, and it made it possible to refine a number of professionally important operations related to transfer from one craft to another, conducting scientific studies outside the spacecraft, etc.

Thus, the training of cosmonauts for flights aboard Vostok and Voskhod spacecraft, which was conducted in 1961-1965, made a substantial contribution to the development of cosmonautics. The practical result of this work was the inception and development of BMT, which subsequently (at the next stage of development of cosmonautics) served as the basis for the system of medical support of space flights [2, 9, 10, 15].

The new element in development of BMT during the missions aboard Voskhod spacecraft was refinement of elements of medical support of crew work in a vacuum, in particular, the development of special physical training that provided for reliable physical endurance of cosmonauts wearing space suits.

As a result of the systematic refinement and evolution of development of methods of BMT, the training became more differentiated. The following directions could be distinguished: medical monitoring of the health status of cosmonuats, dynamic observation, CPE in stages and others; training the crews to use special gear and onboard medical supplies, including prevention of deleterious effects of weightlessness; conditioning to deleterious space flight factors; physical training; medical support of professional activities of cosmonauts; medical support of crews at different phases of space flights.

It must be noted that medical screening ceased to hold the significant place it had at the previous stages, and it became the norm only at the stage of recruiting cosmonaut candidates. Instead, preventive problems directed toward preserving professional longevity and high efficiency of cosmonauts began to be solved in the course of BMT.

The next space program that determined the next stage of BMT consisted of the missions aboard the Soyuz spacecraft, which were intended to conduct a considerably greater volume of studies than before. New and more complex tasks were performed: docking in near-earth orbit; extensive maneuvering in solo and group flights; long-term flights lasting many days; scientific and technological, as well as biomedical research.

The ultimate purpose of this program was to solve the main problems related to creation of near-earth stations.

For this reason, the most important tasks of BMT to support these flights were to conduct in-depth studies of the potential capabilities of man and to develop methods for comprehensive training in the interests of using these capabilities to perform the specific tasks of missions.

The possibility of many-day manned flights was tested in the course of the Soyuz missions. Thus, a flight lasting 18 days was made aboard the Soyuz-9 spacecraft. The results of examining functional disturbances occurring in cosmonauts during the flight and in the readaptation period made it possible to work out substantiated recommendations aimed at conditioning the body for longer stays in space. Old methods, principles and approaches to BMT of cosmonauts were refined and new ones emerged.

The important distinction of this stage of BMT was its individual orientation, both in the sense of demonstration and consideration of individual psychophysiological traits and development of training programs for each cosmonaut individually and e crew as a whole.

It must be noted that, at this stage of development, BMT was formed with due consideration of existing traditions and the existence of stages in professional training of cosmonauts. A special form of training emerged from the experience of training cosmonauts to conduct scientific and technological experiments, special medical training, which includes both general medical training and teaching cosmonauts the practical skills for working with medical equipment, rendering self-help and mutual help, conducting medical observations.

In the 20 years of manned flights in space, the technical equipment used in training has increased significantly; laboratory and research bases were created. More refined versions of domestic medical technology were developed and are being used.

From this survey of the inception and development of BMT, we see that among the many problems related to creation of long-lasting manned stations, the problem of the "human element" was one of the basic ones. The advances in solving it, which were achieved by the start of the 1970's, were largely attributable to the purposefulness of BMT and biomedical research conducted on the Vostok, Voskhod and Soyuz programs.

The first Soviet station, Salyut, was inserted in near-earth orbit on 19 April 1971. The main objectives of its mission included a set of biomedical studies directed toward further investigation of the physiological capabilities of the body during long-term space flights lasting many weeks and psychophysiological capabilities of a researcher-cosmonaut under specific life support conditions.

Since that time, research on the Salyut program has successfully continued and been expanded. The programs of this work are quite diverse. They include biomedical research dealing with the following: study of the long-term effect of space flight factors on man and distinctions of his adaptation to space flight conditions; determination of the efficacy of special preventive agents and measures that lower the adverse effect on man of space flight factors; investigation of psychophysiological capabilities of cosmonauts with regard to performance of operator tasks; investigation of optimization of the work shift, work week, work and rest schedule; study of problems of psychological compatibility of crew members during long-term missions; investigation of technical medical problems of space ecology; experiments with higher plants, microorganisms and other biological models.

In 1960-1961, BMT of cosmonauts took up over half the total training time. And much attention was devoted to general physical training.

However, the professional training of cosmonauts, study of construction of spacecraft, as well as conditioning on a complex simulator in order to refine skill in controlling the main onboard systems of the spacecraft were the basis of preparing cosmonauts for space flights.

In 1966-1967, at the stage of training cosmonauts for missions aboard Soyuz spacecraft, BMT took up one-third of the entire time spent on preparing the cosmonauts. At this stage, the most complicated element was training with the use of a complex simulator, due to the increase in number of operations to be refined. Training on a simulator to learn the operations for docking spacecraft took up considerable time in the professional training.

In 1971, during the preparations for flights aboard the first Salyut orbital station, BMT constituted less than one-third of the time spent on all forms of crew training. This can be attributed to the improved living conditions and availability of rather effective preventive agents on board, which made it possible to replace some of the preflight BMT with measures performed in flight.

These data by no means signify a disregard for BMT. A considerable place is reserved for it in the training. However, attention is devoted mainly to preventive measures that assure satisfactory fitness of crews during prolonged exposure to weightlessness, better course of the readaptation period and good restoration of the initial functional state after completing a space flight.

The results of the laboratory studies with simulation of the effects of weightlessness on man made it possible to undertake forecasting of the nature and mechanisms of development of probable functional and structural changes in the body arising in the course of long-term space flights. At the same time, the promising directions were defined for development of ways and means of preventing the adverse effects of weightlessness.

BMT of crews for working on orbital stations and development of appropriate work schedules for cosmonauts in flight were attributable to the need for further extending man's exposure to weightlessness. At the present time, in spite of the definite advances in space medicine, it is still difficult to answer the question of whether man will be able to live and work normally under weightless conditions in the course of a mission lasting many years, even if all possible preventive measures are performed. For this reason, the medical research aboard the Salyut-4 station included the study of changes occurring during long-term flights and mechanisms of the body's adaptation to weightlessness, as well as evaluation of the efficacy of preventive measures in preserving health and maintaining fitness of cosmonauts during flights and after them.

Analysis of the results of medical examinations during the flight revealed that the observed changes in physiological parameters generally conformed with the preflight predictions. These changes were the result of adaptation to the conditions of a long-term space flight, adaptation to stress related to the distinctive elements of the flight. A high degree of efficiency and activity of the cosmonaut in flight was observed, as well as psychological and physiological resistance. At the present time, one of the key problems of adaptation is to find the ways and means of increasing man's resistance to brief and prolonged effects of extreme factors in the environment. BMT plays an exceptionally big part in solving this problem. The effectiveness of its methods and means will probably be instrumental in the continued development of manned space flights.

As a result of the studies, preventive agents were proposed against the adverse effects of weightlessness, in particular on the skeletomuscular system.

The set of preventive measures developed and used with success aboard all orbital stations of the Salyut type includes devices that allow for physical exercise in weightlessness, training G suit designed for long-time wear, vacuum chamber to create lower body negative pressure (LBNP), postflight preventive suits, as well as special fluid and salt supplements to the diet, which increase circulating blood volume and which are used at the end of the flight, just before the descent to earth.

The high efficacy of the set of preventive measures was proved during missions aboard the Salyut orbital stations, particularly during the 63-day flight of cosmonauts P. I. Klimuk and V. I. Sevast'yanov aboard Salyut-4.

These preventive measures made it possible to guarantee to a significant degree preservation of fitness [efficiency] of cosmonauts during long-term flights with less time spent on training than on BMT. This also made it possible to augment the absolute volume of professional training.

In conclusion, it should be noted that there was a qualitative change in content of BMI after the series of missions aboard the Vostok, Voskhod, Soyuz spacecraft and Salyut orbital stations. There was considerable development of preventive measures used in flight to prevent (remove) the harmful effect on the body of deleterious space flight factors.

While the crew that participated in the 18-day space flight required considerable correction of health status, at the present time cosmonauts feel much better, even after longer flights, and this is unquestionably aided by the successful development and use of the set of preventive measures used in flight and the readaptation period.

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PSYCHOPHYSIOLOGICAL SCREENING--STATUS AND PROSPECTS

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[Article by N. N. Gurovskiy and M. A. Novikov, submitted 30 Oct 80]

[English abstract from source] The major stages in the development of psychophysiological selection of cosmonauts in the USSR are discussed. The psychophysiological selection was originally based on the data of psychoneurological expertise of the flight personnel and achievements of aviation psychology in the USSR. This was followed by the development of psychophysiological research, using instrumentation and simulation flights. Further complication of flight programs and participation of non-pilot cosmonauts (engineers, scientists) necessitated detailed study of personality properties and application of personality tests. At the present stage in the development of psychophysiological selection great importance is attached to the biorhythmological selection and methods for studying man's capabilities to control his own emotional, behavioral and autonomic reactions as well as environmental parameters. The review also discusses in detail methods of group selection and problems of rational selection of space crews.

[Text] It is difficult to find in history an event of such enormous significance as the first space flight by a Soviet man, which had been so thoroughly and comprehensively planned. In addition to development of unique technology, there was broad and systematic investigation and substantiation of man's ability to make this unprecedented breakthrough into space. The flight of Yu. A. Gagarin, which demonstrated the advances of Soviet science and the power of Soviet technology, heralded the birth of a new branch of science, space medicine.

The first steps in this direction of science are inseparably linked with the solution of numerous problems of medical screening. It was important that the first cosmonaut candidates were military pilots, people who, by virtue of the specifics of their profession, had the set of psychological traits necessary to learn new techniques related to aviation.

Psychophysiological screening of cosmonaut candidates was based primarily on the knowhow of expert medical certification of pilots [1] and advances in Soviet aviation psychology [2]. The principles and methodology of medical certification of pilots determined the substance of the first stage of development of psychophysiological screening, which was strictly expert in nature and laid emphasis chiefly on mental and somatic health, and the possibility of overcoming emotional stress. However, very soon it became apparent (already in the course of training

the first detachment of cosmonauts) that mental and somatic health does not automatically imply fitness for a job, the concrete content and conditions of which are not quite certain.

Much attention was devoted to the functional capabilities of the body and nervous system.

There was considerable development of laboratory methods of examination with the use of functional load tests, simulation of essential elements of the main factors of space flights ("reproduction principle" of F. D. Gorbov and M. A. Novikov [1]).

The anechoic chamber method, which was developed and successfully executed, made it possible to deliver various stimuli to a subject, in particular, to observe his behavior continuously for long periods of time, to determine the forms of adaptation to new conditions, means of overcoming occurring tense situations and nature of explanations and self-accounts, in addition to providing practical familiarization for the cosmonauts with social isolation, sensory deprivation, regulated activity and communication, as well as other space flight factors. It should be added that clinicopsychological studies are well-supplemented by the anechoic chamber method, which permits prolonged polyeffector recording of autonomic functions.

Polyeffector recording in an anechoic chamber made it possible to assess the dynamics of autonomic functions in the course of a day and of the entire period of isolation, to determine the "physiological cost" of the subject's work by means of psychological techniques using instrumentation. At the same time, while there was obvious predominance of the psychophysiological approach in the anechoic chamber method, there was also some development of the personality-oriented direction. In screening cosmonauts, increasing attention was given to distinctions referable to behavior, performance and emotional reactions in problem situations, in the presence of uncertainty and "novelty."

N. N. Gurovskiy and F. D. Gorbov [3] defined the "main parameters of the state of the neurological and psychological systems" under the influence of various factors as follows:

1. Emotional reactions and behavior while undergoing the forms of special training that are notable for their substantial effect on the mind (parachute jumps, rotation on centrifuge, flights in aircraft, prolonged isolation, some forms of exercises, etc.).

2. Ability to perform accurately the assigned work during the same forms of special training, as well as during special-purpose psychological tests.

3. Emotional reactions and behavioral distinctions under the influence of "novelty" as an independent psychophysiological factor.

4. Ability for active recreation, to relax at specified times during isolation and rapid return to an active state.

These "main parameters of the state of the neurological and psychological systems" found vivid expression in the prelaunch psychological conclusion, in which it was noted that the following traits were inherent in Yu. A. Gagarin: adequate reaction to "novelty," rapid orientation in his surroundings, ability for self-control,

highly developed ability to relax, even for short periods scheduled for rest, to fall asleep quickly and wake up on his own at the specified time; absence of fluctuations of efficiency in the course of the day, ability to react quickly and properly both to stimuli that were scheduled and sudden, random ones. A sense of humor, good nature and ability to joke were the individual traits of Yu. A. Gagarin [3].

The first stage of development of psychophysiological screening, which was directed toward solving the main problems (to prove that man can survive in space and perform purposeful work there on a professional level) was brilliantly justified by the successful completion of the first flights. The principles and approaches inherent in it made it possible to define the major directions of future development of psychophysiological screening.

More in-depth examination of the personality of each cosmonaut, beyond the framework of determining his functional capabilities as an operator [4], was required because of the more complicated programs of subsequent missions, substantial extension of the flights, the need to conduct numerous studies aboard the spacecraft and recruiting nonpilots (research engineers, flight engineers, and others) in the detachment.

In addition to steps to detect latent pathology, adverse individual mental states arising in model studies, expert situations and under natural conditions, we began to use, for in-depth studies of personality traits, numerous flight programs that provided for inflight screening among potential candidates of those that were the most suitable because of their psychological traits and distinctions, who could perform the flight mission the most efficiently.

In addition, study of the personality is of particular value to gain a clear idea about the events that develop aboard a spacecraft (since information about them can be received only as interpreted by the cosmonaut), for proper evaluation of verbal and behavioral reactions to various flight situations, distinctions of interaction between a given cosmonaut and other crew members and ground-based service operators. Finally, organization of leisure time is also closely linked with personality features, tastes and habits.

Use of various methods of personality testing played an appreciable role in solving these problems. Of the nonprojective tests (questionnaires), the most intensive use was made of MMPI, Ayzenko test and, later on, the Kettell test also.

The advantages of these tests are that they are portable, speedy, no significant special training is required to conduct the tests and then process the results. The flaws of these tests include the obvious orientation of the MMPI toward detection of psychopathological states (which sometimes elicits a protest on the part of an individual known to be in good health who has undergone it before), the intrinsic possibility of submitting in the answers an "improved model of oneself," which best meets popular social requirements of a cosmonaut or personal ideas about the traits that a cosmonaut should possess. It was shown that the use of MMPI by researchers and comparison of its results to the data obtained from clinicopsychological observations and other tests is desirable, in spite of the fact that it has scales directed toward detection of insincerity and correction of the results. In this sense, projective tests differ favorably from nonprojective ones, in that the results cannot be predicted by the subject.

The test of the Swiss psychologist and psychiatrist, Herman Rorschach, became the best known of the projective methods. In this test, diffuse black and white, and colored blots are presented as stimuli. This test requires thorough training of the specialist and much research and clinical experience.

Another popular method is the TAT (thematic apperception test), which was developed by Murray and Morgan at the Harvard Psychological Clinic.

A modification of the apperception test, PALT (O. N. Kuznetsov) has made a good name for itself in cosmonaut screening; it is not based on images, but on written material and evaluation of degree of social adjustment. The Rozenzweig test also became popular.

At the same time, the practice of using personality tests revealed that it is extremely dangerous to be too enthusiastic about them. The test results could easily hide the living being with his hopes, goals and ambitions, concrete manifestations, behavior, reactions in everyday life, tense social and model situations.

One can gain integral comprehension of a person solely by studying his practical endeavors in its different aspects, ranging from behavior and reactions in the customary home and work group situation to performance under new conditions, in particularly difficult model or real stress situations, when working on a mock-up, during different tests, etc.

It is only through prolonged, thorough and professionally organized observation, along with the results of personality tests and a significant assortment of psychophysiological methods that a comprehensive portrait of the personality can be obtained, a confident prediction be made of performance of professional work during space flights and endurance of its factors.

In previous years, researchers tried to plot the so-called professiogram of a cosmonaut. At the present time, when flights last over half a year, it is becoming apparent that such efforts are fruitless. The profession of cosmonaut is unique, not only because it imposes great demands on man and requires lengthy, complex and diversified training. The individual selected for this occupation, as well-put by R. B. Bogdashevskiy, a prominent specialist in space psychology, must be both a pilot and an operator, operating and maintenance engineer, specialist in electronics, mechanics, chemical machine building, as well as a home maker and cook.

The range of his duties is unusually broad. Moreover, space flights have ceased to be experimental, when all that was required was to endure the difficulties and discomfort of being in the small and sealed cabin of a spacecraft.

At the present time, space flights are an important part of life itself, where the professional specialty of man is totally utilized, serving professional interests dealing with both space and ground-based aspects.

All this imposes new demands on the personality or, more precisely, makes it necessary to disclose the aspects that were already named in the first studies, but had not been theoretically or methodologically completed at that time.

Here, we should mention the following directions:

Man's ability to control the parameters of his habitat, in particular, the internal habitat, ability to control emotional states and physiological functions.

Characteristics of biological processes, resistance to desynchronosis.

Behavioral distinctions of the crew, quality of interpersonal interaction in an autonomously working group, problems of psychophysiological compatibility.

Initiative, independence, the desire to creatively transform working conditions, active control of many parameters of the habitat are important personality traits in cosmonauts. Such traits are acquired by man, to a significant extent, as a result of life experience under conditions that resemble flight (wintering projects, expeditions, etc.), or in an atmosphere of constantly overcoming difficulties in order both to organize one's behavior and reactions, as well as control circumstances for optimization thereof.

In many respects, the ability to transform one's emotional state can also be acquired. At the present time, formed traditions are being overcome by means of special techniques based on so-called biological feedback. The theory of these methods is based on the research of I. P. Pavlov and K. I. Bykov (on corticovisceral connections) and Yu. M. Konorskiy (instrumental conditioned reflexes). These methods, which are presently being developed everywhere (both in the United States, Canada, other foreign countries and in the USSR), in addition to their main purpose, are of enormous value for screening individuals who have to work under complicated conditions. Our experience with these methods (control of emotional state on the basis of control of electrodermal resistance), as well as other methods based on feedback, shows that individuals who perform their professional work well in stress situations (just like test pilots) present the most efficiency when working with the use of methods based on biological feedback.

Thus, these methodological approaches have much prognostic significance in evaluating performance of professional duties during space flights.

There is no need to prove the desirability of studying biorhythmological processes in cosmonaut candidates and cosmonauts. In spite of the obvious good organization of work and rest schedule aboard Soviet spacecraft, the problem of desynchronosis as a manifestation of the general adaptation syndrome [5, 6] retains its importance. Moreover, stability of rhythmic processes of the body and capacity for painless change therein reflect tolerance to stress factors.

The difficulty of using biorhythmological approaches in the specific work of screening is due to the significant volume of work and it requires a drastic increase in time reserved for this, whereas the methodological equipment available today provides for accurate forecasting [7, 8].

An unquestionally promising direction is the one developed by V. I. Myasnikov and his coworkers, which is related to evaluation of sleep and transient processes, since sleep must be viewed as an integral indicator of personality traits and distinctions referable to adjustment to new conditions.

Questions of interpersonal interaction in communicating and working together have long since and justifiably drawn the closest attention of specialists in the most

diverse fields. This is understandable, since knowledge of the main patterns and mechanisms of communication opens the way toward deeper self-knowledge, rearing, education, optimization of human relations and "the psychological climate" in collectives and social groups.

We know of a considerable number of serious works dealing with different aspects of this problem: sociopsychological, sociological personality, pedagogic, communicative, perceptual, etc. At the same time, one rarely finds studies that trace the psychophysiological aspects of interpersonal interaction. However, it is particularly valuable to understand the physiological and biochemical changes associated with interpersonal processes, since this helps learn the meaning and significance of the dynamics of behavioral reactions, endogenous mechanisms of equating oneself with another individual, interpersonal difficulties and emotional stress, mechanisms and neurophysiological bases of conflict tension.

The need for psychophysiological studies of interpersonal processes increases immeasurably during the prolonged stay and joint work of small groups of people under extreme conditions, closed ecological systems of spacecraft, underwater laboratories and underground sites. Such living conditions are growing more and more widespread in view of the increasing need of mankind to develop new areas. Technological progress now enables man to penetrate, live and work in environments that are particularly aggressive, such as space, deep waters of seas and oceans, high latitudes, including previously inaccessible parts of Antarctica. Habitability under such conditions is related not only to aggressiveness of the environment, which requires organization of special means of protection and life support systems, but the effects of such ecopsychological factors as social isolation and deprivation, special forms of spatial organization of a small group, specific forms of interaction with other social groups, control and monitoring services.

It has been shown in many works that sensory and perceptual deprivation could elicit a complicated set of disturbances referable to perception and body schema, disintegration of mental processes, diminished motivation and many other changes. Many works dealing with isolation are indicative of the possibility of diverse changes, including pathological ones, in some cases.

The forced nature of communication, limitation of social contacts and, at the same time, excessiveness thereof, excessively close contact with a limited group of people, being compelled to alter customary behavior standards, the need to revise many conventional conceptions, role orientation, the impossibility of satisfying many social and spiritual needs merit special discussion under conditions of social isolation.

The spatial organization of small groups in the cabins of spacecraft that are limited in size is characterized by the presence of common working and living quarters, unchanging and specific decor, virtual impossibility of being really alone, the inevitability of invading "the territorial waters" of one another. All this has a significant effect on the nervous system and alters the nature of socialization and interpersonal processes.

Dissatisfaction with sociometric and conventional sociopsychological methods for settling questions of group screening and manning spacecraft crews led to development of integrative methods that simulate instrumental and verbal group interaction,

such as different variants of the homeostatic method, paired verbal test and a few others, in the laboratory of Prof F. D. Gorbov, one of the founders of space psychology.

The valuable features of these methods a.e that they permit recording physiological parameters reflecting the level and distinctions of emotional and autonomic tension, determination of the "physiological price" of participation in the interpersonal process.

At the present time these methods are well-known, and there is no need to describe them in detail. Let us merely recall that the homeostat is an interrelated bioengineering system, in which people (operators) achieve agreed upon decisions by manipulating by means of controls the readings of hand-equipped dials (both their own and their partners').

It has been demonstrated that the tactics of controlling interpersonal interaction are generally used by individuals who are actually in control of a given group, the leaders of such groups. It was also found that leader tactics require certain typological traits in the subjects: strength of the main nervous processes, lability and equilibrium thereof. Thus, with the homeostat it becomes possible to determine the effectiveness of interaction in a small group, as well as the distribution of functional duties in it. This model of group interaction is convenient to use in studies, and this can be attributed to the following: the conditions of per ormance are absolutely identical for all subjects; the difficulty of submitted homeostatic problems is strictly graded (by means of alteration of coefficients of correlation), and it is possible to work in the range of easily solved, difficult or unsolvable problems; it is easy to monitor performance visually, as well as by recording the solution process and physiological parameters of the subjects.

The paired verbal test, which was developed in 1961-1962 [9, 10], is a modification of the well-known word test. Two subjects participate and their task is to respond to stimulus words as quickly as possible (trying to do so ahead of the partner). These stimuli are listed in programs, each containing 30 words and one following the other at short intervals (5 s), which transforms the test into a specified verbal activity. During the test, associative reactions are recorded on tape and ink-writing oscillograph, on which physiological parameters (pulse, respiration, galvanic skin response and others) are also recorded.

In addition to the methods described, which record rather accurately the parameters of performance and autonomic reactions, wide use is also made of clinicopsychological observation of communication and interaction while the subjects work together to monitor equipment, conduct preventive and scheduled work, apply electrodes on one another, during group discussions, sports, i.e., where partners are compelled to come into physical, instrumental and verbal contact. The reliability of data thus obtained depends on the competence of the observers. For this reason, the method of expert evaluation is used to objectivize such results.

The desirability of interaction of the cooperative and competitive types of interpersonal interaction is attributable to the substance and distinctions of real and simulated forms of activity involving small groups of people. However, the concepts of "type of activity" and "type of interaction" are not identical in all cases. It was shown that a problem of the cooperative class is often viewed by subjects as

competitive, or vice versa, depending on many factors (existing relations, social and personal sets, ultimate goals, motivation, etc.). In addition to these factors, the degree of awareness of extent and specifics of personal, individual contribution to joint activity, as well as one's role in the group acquires much significance.

Distinct awareness of one's role in the group at a given point in time is quite typical of individuals who control the interaction process as required, rather than when ordered, given commands or because the individual has claims on the right for decision making.

When the subjects work on the homeostat, leadership is determined by a number of factors: skill in control functions in small groups, role position in a specific group, individual psychological distinctions, high coefficients of centrality in nonsymmetrical structures of the homeostat. Tests involving several hundred small groups of 3 to 8 people differing in purpose (from random groups in model studies to groups whose members are linked through many years of work) made it possible to determine that a leader is always characterized by a high level of awareness of his role in different situations. The partners he leads are not fully aware of the entire complexity of a situation, they are easily satisfied with temporary achievement of the specified position of the dial needle apart from the general group goal and, in a number of cases, they exaggerate their own role in reaching this goal. These observations made it possible to expound a thesis concerning differences in fullness of conceptual models of group situations for leaders and those who are led.

When the actions of two subjects claiming to be leaders are not sufficiently coordinated, "counteraction, a distinctive struggle for the ultimate route" arise with behavioral reactions (motor disinhibition, remarks addressed to partners, disapproving looks directed at them, etc.), i.e , signs of conflict stress.

The activity loses elements of cooperation and is distinctly competitive. In this case, competitiveness, which does not ensue from the substance of the activity, is interpersonal and rather random in nature.

When recording physiological parameters while solving simple problems that do not require sharing the functional duties of homeostatic tasks, some degree of work tension of psychophysiological functions is observed. There are changes in heart and respiration rate, high-amplitude oscillations appear in the galvanic skin response, the EEG shows desynchronization during problem solving and reappearance of α-rhythm in the breaks. The magnitude of these changes may fluctuate; however, uncertainty of the electrographic patterns persists because of the similarity of performance of subjects who implement "natural" tactics, i.e., try to counteract for an erroneous needle position. Since activity is simple in this case, it is easy to achieve the required coordination of actions, the problems are solved rapidly (within 5-15 s), no conditions arise for manifestation of interpersonal tension, and the interaction is clearly cooperative in nature.

When the problems are made more complicated by deepening mutual relations, when sharing the functional duties becomes a mandatory condition for a successful solution, distinct differences are demonstrable in the electrographic patterns of emotional and autonomic elements of tactics applied by the leader and follower.

Another, more complex form of complementary and cooperative interaction is work on the homeostat, in which control of the decision process smoothly shifts from one partner to the other, depending on the developing conditions. Such actions are particularly coordinated, and they are not associated with conflict reactions. Psychophysiologically, the recorded parameters of two interacting leaders are close to one another, and there is persistence of some emotional and autonomic tension as a reflection of the wealth of the conceptual model of the situation for both subjects. At this time, the follower (followers) presents typical psychophysiological patterns: periodic tension alternating with relaxation as the time of decision comes really or seemingly closer. In the case of prolonged and persistent opposition, there may be impairment of psychophysiological functions arterial pressure rises, tachycardia appears, etc. However, the most marked changes in psychophysiological parameters are demonstrable with development of conflict tension, which readily appears when there are failures in solving diverse problems and dissatisfaction of partners with the actions of one another.

In the paired verbal test, as we have stated, competition is present because of the very nature of the verbally specified activity. The leading partner has some advantage: he works on an audio communication channel without a partner, experiences less influence on the nature of associative reactions, etc. The influence on the trailing partner is always rather strong.

The frequent demonstration of coinciding fluctuations of pulse rate in some partners is among the physiological reactions associated with performance that merit special attention. In some cases, this coincidence was striking and resembled resonance processes. A special verification of this phenomenon revealed that such coincidences were not demonstrable when comparing the pulse curves of the same subject, or curves of subjects working at a different or the same time, but in different rooms. This phenomenon was demonstrable only during simultaneous work in the presence of one another, and it could even be present when only one of the subjects gave the answers, while the other was told to remain silent. It was subsequently shown that there could be enhancement of synchronism of pulse rate in the training process. The nature of this phenomenon has not yet been clarified. However, the presence of slow components (frequency of 10-20 s) on the curves, resembling Meyer's waves, could be indicative of the possibility of synchronization of oscillations in the hypothalamic system. Synchronization of pulse curves is observed the most with the cooperative type of interpersonal interaction between partners performing a paired verbal test, or else in competitive situations where the competition is limited to verbal reactions and does not lead to negative behavioral, postural and intonational reactions.

The link between the phenomena of coinciding pulse reactions and imposition warranted the assumption that the "phenomenon of imposition penetrates into the autonomic emotional sphere."

The results of studies revealed that, in a number of cases, pulse coincidence is not associated with a marked imposition phenomenon. Apparently, the nature of these reactions cannot be identified at this time, but perhaps investigation thereof will open the way to demonstration of the neurophysiological mechanisms of mutual induction, as well as empathy.

In the case of acute competition and development of negative behavioral reactions (disappointment, dissatisfaction, submissive tone, paucity of intonation and others),

there is a drastic decrease in coinciding pulses. The coefficient of correlation of sign of such curves is in the range of 0.43-0.58. However, distinct counterphases of slow pulse components are observed visually in a number of cases.

As with the homeostatic method, with the paried verbal test one can observe competitive cooperative and complementary cooperative types of interpersonal interactions, as well as complementary competitive interactions. Eivdently, it would be quite promising to consider manning special purpose crews and small groups that must act autonomously under extreme conditions from the standpoint of "congruence" and "complementarity" principles.

It is easy to assume that in such situations a group with flexible psychological structure, the individual traits of members of which are mutually complementary and interchangeable will be effective; some degree of "incompatibility" of partners is not to be negatively rated when there is a high degree of mutual motivation and desire for cooperation. The question is broader than determination of psychological compatibility of group members, construed as coincidence of sets, emotional and volitional traits, and a number of other personality traits. The recruiting of a group that will have to act autonomously also means positive forecasting of its adaptability, ability to maintain homeostasis in critical situation and group integrity over a long period of time.

When certain personality traits are the same, two or more individuals who are, for example, "sociable," may find satisfaction in the same social environment and thus establish satisfactory associations in the same individual goals and similar satisfaction of needs. Haythorn describes the occurring type of relations as "congruent" [11]. He also has described "complementary" interpersonal relations, which refers to situations where individuals with different personality traits without mutual support are disposed to collaborate. It is stressed that in the interaction of two or more individuals a conflict develops only when the personality traits are "competitive." Haythorn [11] found confirmation of his hypothesis in a number of works, although the style of their arguments and armamentarium of test procedures were limited to sociopsychological conceptions.

For the researcher who has taken on the task of recruiting the above-described groups, it is much more important to identify the psychophysiological mechanisms which are the basis of a certain type of relations in a group. Here, the choice of test methods is directed toward demonstration of the distinctions of group interaction in different interindividual combinations, investigation of the ability of individuals to share the experiences, mood and feelings of their partners and, thus, differentiation between genuine and demonstrated solidarity.

The results of numerous studies dealing with psychological group screening of special purpose crews enabled the authors, who evaluated actually formed groups in terms of "congruence--complementary," to qualify them according to the degree of effectiveness of long-term performance in autonomous conditions.

Congruence of interaction is related to easy demonstration of psychological structure, speed of assuming functional roles, demonstration of relations of the "leader-followers" type at the very first session, often coinciding with those officially established.

Teaching skill in interpersonal interaction lasts longer in the case of the complementary type. Under actual conditions, this was confirmed by the fact that there was a mandatory period of discussion in development of such groups. At the same

time, the partners demonstrate better ability to use the means of mutual adaptation, flexible tactics of action. There are impressive examples of group behavior when a specified competitive situation is subjectively perceived and actively processed by partners as activity of the cooperative type.

According to Kelly and Tibaut [12], the extremes of pure cooperation and pure competition are rare, and the motives of the partners are mixed. However, the psychophysiological approach makes it possible to demonstrate tendencies in group members for coordinated reactions to a situation; this is manifested by the same direction of dynamics of physiological functions.

Groups of the congruent type, which achieve success through interaction, present some inconsistency in problem game situations. According to V. Ye. Lepskiy [13], pairs of subjects who solve problems on the Homeostat device with great effectiveness do not win in problem situations over pairs that solved Homeostat problems with low effectiveness. Apparently, this is attributable to the presence in congruent groups of "rigid" structures with fixed orientation of individuals toward "leader-follower" tactics, which has an adverse effect on performance in problem situations.

"Congruence" of group members is often the consequence of firmly acquired conventional roles, and the partners tend to display the social norms of behavior that correspond to them (on the order of dominance-subordination). This is particularly manifest when using methods involving verbal interaction ("paired verbal test," testing creatively cognitive activity of the group).

Thus, the congruent type of interaction in a group can be considered desirable chiefly for the performance of brief tasks. On the whole, it is characterized by a certain rigidity of behavior, lack of flexibility in tactical decisions in probabilistic problem situations.

The complementary type of interaction requires in-depth and rather lengthy group training with mutual teaching, formation of group psychological structure consistent with the tasks set forth. This type is considered the most reliable for a group that is to function for a long time under extreme conditions, since it stimulates creatively cognitive activity of partners, is instrumental in making optimum decisions in uncertain situations and maintains group solidarity under monotonous conditions.

A complex psychophysiological examination for the purpose of recruiting special purpose groups must be directed toward demonstrating the following group characteristics:

1. Distinctions of group interaction: The nature of distribution of functional roles, group structure and its relation to socially regulated relations are established with the instrumental tests ("homeostat," "paired verbal test"). Successful performance appears as a prognostically positive sign, combined with demonstrable congruent physiological parameters (for example, heart rate). Interchangeability of tactical actions, delegation of control functions to the partner when the situation warrants, and the group's ability to overcome the "psychological barrier" in an expert situation also merit attention.

2. Tacts of action in problem, probabilistic situations. Several tests (games with binary choice, work on "simulator for group decision making") are used to assess phenomena such as the ability to work out a joint optimum decision in an

uncertain situation, assimilation of the content of the partner's "cognitive field," "shift toward risk" with group polarization in this direction.

3. Creatively cognitive activity. In the group variant of classical projective tests (Rorschach, TAT, PALT), developed by I. S. Zamaletdinov and O. A. Zhdanov, examination is made of the possibility of improving the cognitive style of an individual's performance by means of the process of communication, mutually influencing one another as to individual cognitive styles. The established fact that interaction has a stimulating effect on overall performance enables us to qualify such a group as prognostically reliable under conditions of long-term autonomous existence.

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PREVENTION OF PSYCHOEMOTIONAL DISTURBANCES DURING LONG-TERM SPACE FLIGHTS BY MEANS OF PSYCHOLOGICAL SUPPORT

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 2, Mar-Apr 81 pp 25-29

[Article by V. I. Myasnikov and O. P. Kozerenko, submitted 30 Oct 80]

[English abstract from source] A number of supportive and rehabilitative measures forming so-called psychological support can be used to prevent potential psychoemotional disorders in crewmembers during prolonged space missions. The use of these measures in the Salyut-6--Soyuz 96-185-day space flights has shown their efficiency in terms of expansion of the "psychological living space" and maintenance of a high emotional and working tone of crewmembers.

[Text] Prevention of psychoemotional disturbances among crews of spacecraft is one of the pressing problems of space medicine, that emerged with particular urgency in connection with long-term manned missions [1]. It dates back to the period of preparations for and execution of the first missions into space, when specialists did not have enough information about the effects of flight factors on the human body and mind. However, even then [2] it was logical to assume that the psychological distinctions of the flight and nature of work (novelty, uniqueness of surroundings, high degree of responsibility for one's actions, in which mistakes are inadmissible, and others) would create considerable stress in the cosmonauts, the prediction of outcome of which is actually linked with the prediction of endurance of the flight itself. For this reason, the entire system of screening and training man for the first quite brief (days, weeks) missions, an important element of which was to enhance emotional stability of the candidate, also served the purpose of preventing possible neuropsychological disturbances. The nature of these disturbances was the subject of numerous studies in our country and abroad, which dealt with the problem of so-called sensory starvation, sensory isolation and perceptual deprivation [3-14].

The general outcome of these studies (which were conducted under very different conditions and for different purposes) was the demonstration of significant mood and efficiency changes: apathy, depression, heightened suggestibility, emotional instability, euphoria, low spirits, increased anxiety (panic), subjective discomfort with a tendency toward primitive emotional reactions, irritability, boredom, neurotic reactions, diminished motivation, development of sensory disturbances reaching hallucinations.

In the USSR, F. D. Gorbov conducted a purposeful study of the nature of emotional behavior of cosmonaut candidates, using the method he developed of testing in an anechoic chamber, which reproduces the most fully the psychological distinctions of a space flight [5]. Adoption of this method in the practice of screening and training cosmonauts enabled O. N. Kuznetsov and V. I. Lebedev [8] to create a classification of unusual mental states, which included such forms of psychoemotional disorders as emotional neurotic reactions to the absence of feedback, postisolation hypomanic syndrome, phenomenon of "catathymic negativism" (refusing an activity that does not conform with the emotional tone of affect), eidetic and hypnagogic ideas, sleep disorders and subjectively interpreted ["realized"] dreams, etc.

The above changes, which are attributable to personality and situational factors, emerged as the most likely consequences of isolation during space flights.

However, analysis of flight data referable to the early stages of man's exploration of space failed to demonstrate any noticeable psychological disturbances in the cosmonauts. One could refer with certainty merely to a high level of nervous and emotional stress due to the heavy program of the flight and nature of crew's work (responsible dynamic operations, working in weightlessness within or outside the spacecraft under conditions of increasing shortage of time and altered information field). It is expressly high emotional stress combined with weightlessness that was the cause of the observed physiological changes [15].

In addition, there were typical adaptive changes, particularly during the first missions aboard the Salyut orbital station, due to the effects of the specific habitat and its main factors, wieghtlessness and isolation in a confined area: sensation of blood rushing to the head; basically new organization of movement in weightlessness with the sensation of involuntary, so to speak forced changes in position; more acute sensory perception by virtue of limitation of the customary spectrum of odors, sounds and colors; missing one's family [16].

In the opinion of Leventhal and Lindsley, such changes as adaptive reactions of the human body and personality to being in a spacecraft "... could initiate reorientation--switching from predominantly external orientation to internal, subjective" [17], and "the intensive work of the imagination, prolonged concentration of thinking and daydreams could make it difficult to regain objective consiousness" [17] and, consequently, could present a potential threat to integrity of motivation for professional work.

According to the results of analysis of flight data, this hypothesis was not confirmed during missions lasting up to 63 days (USSR) and 84 days (United States). On the contrary, it was found that man can not only adapt well to the unique habitat in a spacecraft, but work efficiently in it for a long period of time [15]. Nevertheless, the prospect of extending flight tests made it necessary to take into consideration the above consequences and stimulated a search for measures to prevent them.

Wisely spent leisure time aboard the spacecraft, drawing on the way it was spent on earth--in every day life, expeditions, etc.--was considered one of these measures, even at the early stages.

The results of anechoic chamber tests, for example, revealed that under conditions of prolonged isolation the subjects found occupations for themselves during periods

when no work was scheduled: they sang, recited poetry, read, painted [or made drawings], engaged in creative writing and crafts, which the researchers took into consideration when preparing recommendations for organizing the work and rest schedule for cosmonauts [18-20].

During the space flights, there were books, sets of postcards, a chess set available to the crew, concerts were broadcast and occasionally conversations with their families were organized [18, 21].

However, sporadic use was made of these recreational resources: "each member of the crew spent his personal time at his own discretion, since there was no specially prepared program for organizing leisure time" [18], nor was there any scientific theoretical substantiation for it.

It is only later on that the idea was discussed [22, 23] of making use of active leisure as a regulator of level of wakefulness (by means of switching to a different work dominanta or stimulating contemplative activity) in relative isolation and through it as a deliberate influence on both the mental status and fitness [24].

The new stage in the development of cosmonautics, marked by the long-term functioning in orbit of the manned Salyut-6--Soyuz research complexes, was associated with the solution of an exceptionally important problem for space medicine and psychology, that of providing for well-being, good affect and high level of fitness of crew members in the course of missions lasting up to 185 days, with the prospect of successful rehabilitation in the postflight period.

We refer to scheduling a man's life and work in a specific environment, which required constantly high intellectually affective tension (chronic stress).

Of course, under such conditions, "preservation of spiritual equilibrium as a most important prerequisite for productivity of purposeful action and general vital tonus of the individual" [25] could not be effectively provided by relying solely on reserve stability, special mental flexibility and adaptability of man himself. For this reason, it was deemed desirable to introduce special-purpose psychoprophylactic and psychocorrective measures into the system of medical support.

The set of measures that was developed, arbitrarily referred to as psychological support of the crew, was used to prevent and compensate for the adverse effects due to prolonged stays in the informationally altered environment of the spacecraft, under conditions of isolation, remoteness, limitation of social contacts, monotony and sameness of surroundings.

This set of measures was based on the principle of informational factors, which directs itself to providing for personal involvement of crew members in the work [activity], in its motivational, informational and emotional aspects [26, 27].

As we know, satisfaction of man's need of information, including pragmatic, uncertain information [28], emotional experiences [29, 30], emotional satiation [31], is a mandatory prerequisite for normal function of the body and development of the personality. Since space flights are associated with some restriction of natural exogenous sources of satisfying these needs (diversity and freedom of choice of activity, work, exogenous surroundings, socialization, recreation, etc.), providing crews with significant information was viewed as one of the means of preventing deprivation effects.

The problem of organizing leisure time for cosmonauts aboard a spacecraft was resolved by using onboard and ground-based resources. Aboard the station, there were tape and videotape recorders with the appropriate supplies of film. The video and tape libraries, which were assembled in accordance with the preferences and taste of the crews of four long-term missions, included the best specimens of Soviet and foreign movies and stage productions. During the missions, the videotape library was supplemented with new material delivered by the visiting mission crews and Progress cargo craft, including tapes of events accompanying the mission: responsible operations performed by the crews, on the one hand, films of the families, coworkers and friends, on the other. Videotapes of entertainment programs prepared by countries participating in the Intercosmos program were of particular interest.

The problem of counteracting monotony and sameness of the surroundings was resolved by means of unique psychological reconstruction of the habitat. The crews received diversified information: news (Central Radio and Television programs); special selection of news in science, technology, cultural events and sports; musical background during sessions of radio communication, including "functional music" and reproductions of the sounds and noises of earth.*

It was observed that the cosmonauts made more frequent requests (particularly those involved in the first three missions) for transmission of rhythmic music starting with the 2d month of the mission.

This fact, which had also been observed in ground-based experiments involving prolonged isolation and sensory deprivation, is usually related in the literature with the decline in activation of the body, as a result of which there is formation of behavior directed toward a search for stimuli [32]. Under flight conditions, this "search" was effected by the use of background music. According to the cosmonauts, music was played continuously on board, and it was an inseparable component of professional activities. There was background music during radio communication sessions during dialogues and certain work operations that did not require keen attention. Special significance was attributed to the novelty of music programs with long periods without repeating specific works. In addition to music, there was audio background to conversations (the sound of rain, birds singing, city noises, etc.).

The shortage of social contacts was compensated by organizing communication sessions with the participation of representatives in different areas of public life: political reviewers, sports commentators, artists of the theater, movies and stage who, being the only source of information for the crews, also performed an important psychotherapeutic role with respect to deliberate regulation of emotional and motivational states. The special training of individuals who participated in these dialogues included the choice of topics of conversation (in the context of the current stage of the flight and state of the cosmonauts), selection of appropriate musical and dramatic repertoire (functional role of art) and orientation toward the cosmonauts' personality distinctions.

A total of 118 such communication sessions involving about 100 people were organized during the four long missions aboard the Salyut-6 orbital station.

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*Representatives of the Center for Cosmonaut Training imeni Yu. A. Gagarin participated in informational support via the radio communications channel.

As shown by experience, such an approach was quite effective in maintaining the crews' emotional and work tonus. In one of his telecommunications, cosmonaut V. V. Ryumin stated in this regard: "Such encounters help us in our work, they help keep us up to date on the affairs of earth and, to some extent, compensate for the shortage of the usual socialization on earth."

This form of psychological support became the most expressive in connection with the introduction of two-way "Mission Control Center--spacecraft--Mission Control Center" telecommunication, which made it possible to transmit directly such events as, for example, the May 1 demonstration on Red Square, athletic and ceremonial events related to the 1980 Olympics from Luzhniki, the most important events in the life of the cosmonauts' families, etc.

As shown by the results of analysis of verbal behavior after these measures were taken, the share of verbal participation of the crews in radio communication increased substantially, and this effect was observed both during these measures and on the days after them [17].

Psychological support achieved special expression with regard to deliberate regulation of emotional status when there was communication of personal information, in particular through encounters with the cosmonauts' families. As indicated by G. M. Grechko, the encounters with families served as the source of "a most powerful emotional charge." This cosmonaut observed: "Our good mood is upheld by two factors ["whales"], creative work and radio communication with our loved ones." The experience gained in the support of missions aboard the Salyut-6--Soyuz orbital research complex revealed that the need for contact with their families presented some dynamics among the crew members: it became more intensive at the end of the mission.

Personal information was also contained in letters, photographs, special editions of newspapers delivered by visiting expeditions and Progress spacecraft in the form of surprise packages.

The fullness of flight programs with important operations pertaining to control of the Salyut station, extravehicular activity, reception of visiting expeditions and cargo spacecraft, scientific research and experiments did not give any grounds to assume that there was a decline of motivation for work among the crews. At the same time, the experience of high-latitude expeditions to the North Pole and Antarctica indicated that a decline of motivation was the consistent result of long-term isolation and monotony [32].

Information directed at supporting the cosmonauts' personal creative plans, switching their preferences (when they learned new types of work during flight--visual observation, astrophysical and geophysical experiments, etc.) in the direction of lasting interest in unexplored problems and questions of an applied nature in the interests of the national economy. A wide network of consultations with various specialists (oceanologists, volcanologists, meteorologists, glaciologists, biologists, astrophysicists and others) was organized at the Mission Control Center to obtain such information.

Independent importance was attributed to reports concerning the use of the results of the cosmonauts' work and adoption of the crew's recommendations in the practice of ground-based organizations and services.

Sufficient knowhow in organizing psychopreventive work with crews was gained in the course of medical support of the four missions aboard the Salyut-6--Soyuz orbital complex. Its effectiveness (along with other preventive measures) in expanding the "psychological living space," maintaining well-being, emotional tonus and efficiency of cosmonauts is corroborated both by the statements of the participants of these long-term missions and the results of medical monitoring of neuropsychological status throughout the missions.

In conclusion, it should be stated that this practical experience in psychoprevention of emotional disturbances in cosmonauts involved in long-term flights requires further theoretical interpretation and refinement of some aspects of psychological support.

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CURRENT STATUS AND PROSPECTS OF HYGIENIC SUPPORT OF MANNED SPACE FLIGHTS

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[Article by Yu. G. Nefedov and S. N. Zaloguyev, submitted 21 Nov 79]

[English abstract from source] On the basis of their findings and the data published in the literature, the authors review the main results of investigations related to the hygienic maintenance of manned space flights. The paper presents the major problems in this field that need to be resolved in order to maintain adequate environments in space cabins.

[Text] A large volume of research has been conducted to date in the area of sanitary and hygienic support of manned space flights. Introduction of the results of these studies has made it possible to create a habitat in the cabins of spacecraft and orbital stations that is favorable for performing the flights successfully.

However, the increased duration of missions aboard spacecraft and more complex programs of the work of individuals involved make it necessary to conduct broader sanitary and hygienic studies in order to create comfortable living conditions that would be instrumental in retaining high efficiency of cosmonauts at all stages of their missions. It is still very difficult to offer substantiated recommendations on providing comfortable living conditions for long-term flights, since the distinctions of these conditions have not yet been sufficiently investigated. Moreover, it must be noted that extending space missions raises a number of new sanitary and hygienic requirements, since the spacecraft becomes not only the place where intensive work is done by crew members over a long period of time, but also their home with all its inherent household requirements.

When preparing recommendations, one must take into consideration the ways and means of providing for "housing and communal" sanitation tried and tested by many years of history of mankind, but with some corrections. The need for this is determined not only by technical and economic requirements, but the distinctive changes in a number of human physiological functions under these specific living conditions.

By analogy with living conditions on earth, communal hygiene of inhabited spacecraft must have the goal of creating comfortable conditions with regard to microclimate, gas composition of the atmosphere, illumination, noise and vibration levels, as well as aeroion and aerosol composition of the atmosphere. Its task also includes setting the permissible levels of toxic chemicals in the atmosphere

of sealed areas, which are emitted by operating equipment, construction materials, cosmonauts as a result of vital functions and issuing recommendations for development of effective systems for purification of the atmosphere.

As we know, the microclimate of living quarters consists of a set of meteorological factors: air temperature, humidity and velocity; temperature of internal surfaces in the room, light and ion conditions, etc. When setting standards for room microclimate one usually proceeds from the fact that the set parameters must create a comfortable temperature for the body. Comfortable refers to meteorological conditions that assure an optimum level of physiological functions, including heat regulation, with subjective sensation of comfort. The range of thermal comfort must be narrow. Expressly its parameters serve as the norm and are used for heat engineering calculations. However, when people spend a long time in a spacecraft cabin with a constant microclimate, physiological rest of thermoregulation is not desirable, since this could lead to a decrease in heat resistance of the human body [1], and in the case of intensive mental work it could lead to development of sleepy inhibition [2]. This circumstance makes it imperative to conduct extensive studies in order to provide for a dynamic, pulsating microclimate in a spacecraft cabin, and this can be achieved by defining the range of thermal comfort and permissible, beneficial range of fluctuation of the microclimate. Knowledge of the microclimatic range will provide the necessary data for designing automatically controlled systems for providing "pulsation" of temperature and air movement in the spacecraft.

The need for such studies is also due to the assumed distinctions of heat transfer in man under conditions of microgravity, when the absence of convective flow of air could affect differences in perception of heat comfort in a spacecraft cabin, as compared to living conditions on earth. Data have recently been published [3] that confirm this possibility and indicate that there is a probability of local areas of elevated temperature underneath the cosmonauts' clothing as a result of absence of convective air flow.

The absence of convection in weightlessness has caused much interest in questions of movement and scattering of air exhaled by man in a spacecraft. The hypothesis, which was expounded at one time, as to the possibility of formation of local accumulations of gas containing too little oxygen and too much carbon dioxide prompted Keating et al. [4] to conduct studies including mathematical analysis and experiments with models. They analyzed only the effects of movement of the atmosphere caused by breathing and diffusion during sleep or with restriction of movement of cosmonauts, i.e., under conditions of lack of artificially elicited movement. Although the results of the studies with models did show that cosmonauts should not be exposed to the danger of self-poisoning as a result of absence of air movement in some parts of the spacecraft cabin, it is deemed imperative to conduct studies to assess such a possibility in the case of prolonged stays of crew members aboard orbital stations. The results of preliminary studies conducted for this purpose during operation of the Salyut-6 orbital station are indicative of the probability of formation of static air zones in some parts of the quarters and possibility of accumulation there of toxic chemical impurities and carbon dioxide.

For this reason, determination of physiologically neutral concentrations of carbon dioxide as related to different levels of physical activity of crews while in the sealed cabin of a spacecraft is very important. In the opinion of a number of researchers [5-9], up to 4-6 mm Hg carbon dioxide in the atmosphere of a sealed area has no significant effect on the body; it is not desirable to expose man in a sealed area with carbon dioxide content in excess of 7.5 mm Hg, since it could

have a toxic effect. However, it should be noted that the existing classifications of the various toxic effects of carbon dioxide, as related to its partial pressure, were obtained chiefly on the basis of the results of studies, during which the subjects were at rest [10]. All this does not make it possible to use them fully enough for predicting the condition of cosmonauts, especially in cases when they are performing intensive physical work.

The importance of such studies is emphasized by the fact that special relations are established in a selaed cabin between man and his environment, which are manifested by the active formation of products emitted in the course of vital functions [11-16]. The broad studies pursued in this direction [17-18] established that the air exhaled by man is one of the sources of pollution of the air environment of a sealed space, and the levels of various trace impurities in it are quite variable, depending on a number of conditions: individual distinctions of metabolic processes, composition and caloric value of food, motor activity, degree of effect on man of microclimate factors. Moreover, the products of fatty secretion and perspiration, intestinal gases and others could have a substantial effect on overall pollution and composition of trace impurities in the atmosphere of a sealed compartment.

The products of gas emission from polymer items and ornamental-finishing materials proposed for the interior of spacecraft could have an appreciable effect on formation of the environment. Studies of the products of gas emission from over 500 synthetics identified and assayed about 70 different chemical compounds. They included such highly toxic substances as carbon monoxide, epichlorohydrin, hydrogen fluoride and cyanide, and others. It is important to note that the intensity of emission of volatile substances from polymers is largely related to the operating conditions and parameters of the environment. Thus, with change in specific "saturation" with materials in a sealed cabin and presence of high temperature, an exponential relation to concentration of emitted substances was established [19, 20].

The effects of deleterious chemicals present in the atmosphere of a spacecraft on man can be discussed in terms of acute and chronic toxic effects. Particular attention was devoted to the study of the possibility of chronic toxic effect on man of substances containing alcohols with different molecular mass, esters of these alcohols with acetic acid, ketones, aldehydes, aliphatic hydrocarbons, heterocyclic and inorganic compounds [16, 18, 21]. It is known that chronic exposure to alcohols affects renal and liver function; esters [ethers] with acetic acid cause hypotension and irritation of the lungs. Aliphatic and aromatic hydrocarbons have low toxicity, but in high concentrations thay can cause certain changes in some internal organs and elicit a narcotic effect. Heterocyclic compounds have been observed to have diverse manifestations of toxic effects.

As a result of thorough and numerous physiological and hygienic studies, the maximum permissible concentrations (MPC) were determined for many chemicals that are most frequently found in the atmosphere of sealed compartments. The choice of MPC provided for determination of criteria of the quality of air in a sealed compartment, based on identifying the intensity of the physiological reaction as a function of dosage of atmospheric pollution, with subsequent comparison to the dose-reaction curve. It must be noted that the established MPC for chemicals in a sealed compartment with humans are tentative, and substantiation of standards with consideration of safety coefficients can be made on the basis of space flight tests. The reason the MPC for chemicals set in ground-based tests are tentative is that cosmonauts in weightlessness could present qualitatively different reactions to chemicals than would be demonstrated on earth. Moreover, there are sufficient grounds [22, 23] to

assume that, under the influence of cosmic radiation, the different chemical micro-impurities that contaminate the air environment of the spacecraft cabin could change to an ionized state, which would enhance their chemical activity. This could result in an increase in the direct toxic effect of the micro-impurities, as well as create favorable conditions for ion-molecular reactions and appearance of new chemicals with high toxicity in the air environment.

The above factors require the most serious attention when designing manned spacecraft, in particular, systems that are intended to provide a beneficial habitat. It is imperative to develop highly effective systems for removing from the air the entire set of gas impurities and means for reliable monitoring of the levels of chemicals, which are the most demonstrative with regard to sanitation and toxicology, in the air environment of spacecraft cabins.

Development of principles and criteria for standards of air quality in future spacecraft, with due consideration of the specific requirements for living conditions during manned space flights, as well as the main theses of the Soviet hygienic school, should be considered one of the tasks for sanitary toxicology.

Aerosols present a great danger when working in space; they could penetrate into man's respiratory tract in a substantially different manner than when there is normal gravity [24-26]. Man, various materials and life support systems could be the source of aerosol formation in a spacecraft [15, 24]. With regard to the toxicological hazard of aerosols, one must consider the fact that aerosols may act as adsorbents or condensation centers for toxic gases. This circumstance facilitates penetration of chemical compounds into the lower respiratory tract, whereas ordinarily they are retained in the upper respiratory tract because of their good miscibility in water [21]. The difficulty of this problem as it relates to sealed inhabited systems lies in the fact that aerosol particles have a tendency toward increase in number and mean diameter [24, 27].

At the present time, the information about formation of aerosols and nature of deposition of particles and droplets in the human respiratory tract in weightlessness is quite contradictory [26-29, 30]. The absence of direct experimental data does not give us grounds to derive a definitive opinion on this score. Nor has there been definitive determination of the biological effects of ionized aerosols and gases under these specific living conditions [31].

The probability of appearance of the "solar starvation" phenomenon in people, due to ultraviolet deficiency (by virtue of being constantly in the sealed cabin of a spacecraft) is viewed as a serious problem in the support of long-term space missions, since it could serve as the cause of various pathological states. To solve this problem, which has great hygienic and physiological importance, it is imperative to conduct technological design studies directed toward development of special erythemic lamps, or devices that allow solar radiation to come through. In the latter event, it will be necessary to conduct studies aboard a spacecraft. The results of studies pursued on earth with natural and artificial ultraviolet radiation have only limited applications to space flights, since the energy characteristics of solar radiation are not the same in space and on earth. It has been established [32] that the spectrum of solar radiation in space in the range of waves from 0.3 to 0.4 μm has energy of 800-1200 W/m^2 μm, whereas, according to Keller [33], ultraviolet rays in the same wave range elicit necrotic changes in the skin at energy rate of 10 W/m^2.

The possibility cannot be ruled out that there may also be a change in ability to receive ultraviolet radiation by individuals in the sealed cabin of a spacecraft, for which reason preventive erythemic irradiation of cosmonauts should be preceded by special studies to determine how it should be used.

Studies dealing with hygienic evaluation of the effects of noise and vibration on people spending long periods of time in a spacecraft cabin merit much attention. Along with studies to define the maximum permissible and physiologically neutral noise levels and main parameters of vibration, it is imperative to conduct in-depth investigations to determine the distinctions of physiological reactions of man to the combined effect of noise, vibration and other factors inherent in the cabin of a spacecraft ["space object"].

One of the most important problems of modern epidemiology is to study the mechanisms of onset of diseases caused by representatives of human automicroflora. The difficulty of solving this problem is due primarily to the fact that the epidemiology of infectious processes elicited by conditionally pathogenic microorganisms is notable for significant uniqueness, while it retains the main epidemiological patterns [34, 35].

This matter is particularly important in sanitary and hygienic support of cosmonauts in a spacecraft operating for a long time, where the intensity of expression of the transmission mechanism which is the basis of the process of interchange of representatives of the human automicroflora could increase significantly, as compared to ordinary living conditions [36-40]. The results of our ground-based model experiments and studies [36, 41] in space revealed that changes leading to faster expression of the mechanism of transmission of representatives of automicroflora from one individual to another occur at all stages of the transmission mechanism, and they are attributable chiefly to the effects of factors inherent in space flights.

All of the foregoing served as grounds to include as one of the mandatory prerequisites in manning crews the recommendation to screen them for demonstration of individuals with consistently high levels of probable pathogens of diseases among the principles developed for sanitary and epidemiological support of manned space flights. If such individuals are found, they must undergo a set of prophylactic measures. It must be noted that the problem of treating "healthy carriers" of pathogenic representatives of their microflora is far from having been solved in ordinary clinical practice [42]. We consider it extremely important to solve this problem for support of long-term manned space flights, and for this reason a broad front of complex studies must be deployed in this direction.

With reference to the problem of occurrence of diseases among crew members of the "cross infection" type, we should dwell on another, final stage of the mechanism of transmission of microorganisms. Data in the literature [23, 43] indicate that mutual exchange of microorganisms alone is not enough for the recipient to contract a disease. For this to happen, the microorganisms must "take" to the new host, a process that is associated with either development of an infectious process or a "carrier state," depending on the degree of pathogenicity of the microorganism. In the process of "taking," along with epidemiological aspects (expression of the transmission mechanism provided the microorganism reaches the site of its usual localization in a susceptible organism), ecological factors acquire much importance, since the process of "taking" of microorganisms shoud, first of all, be associated with invasion of the microorganism in an already formed biocenological system in man, the microbe.

Consideration of the ecological aspect, or more precisely that of medical ecology, of this problem is attributable to the fact that the habitat environment in a sealed space must participate in this biocenosis, which is based primarily on processes of commensalism that lead to interaction between parasite and host only in extreme cases. In the opinion of some researchers [23], the process of "taking" of microorganisms in a new host would apparently occur when they become part of a new ecological system, which is formed when people live together.

Further investigation of this problem requires many studies using the most diverse methods. This assumption is based on data, chiefly hypothetical in nature, to the effect that human anatomical and physiological distinctions may be of some significance to expression of the process of microorganism "taking": the state of a man's immunological reactivity as determined by congenital and acquired features of this system (genotypic and phenotypic characters); composition of human microflora which is capable of active counteraction to an invading microbe due to competition or antagonism phenomena [13, 34, 35, 42]. In view of the importance of the ecological aspects of this problem, as it relates to the situation when people are in the cabin of a spacecraft, it is deemed desirable, first of all, to pay attention to the study of the nature of antagonistic correlations between microorganisms on different biocenotic levels: on the human integument and in the environment of a sealed compartment. As active factors, one should study not only conditions inherent in space flights, but the proposed preventive measures aimed at normalizing the composition of cosmonauts' microflora or treatment of the environment of the spacecraft cabin.

The data we have obtained [44] concerning the possibility of accumulation and retention of conditionally pathogenic microorganisms on various materials, and involvement in this process of condensation moisture justify consideration thereof as one of the important prerequisites for formulating and solving the problem of "biostability" of polymers which, as we know, are used extensively in spacecraft. In our opinion, this problem should be considered in two aspects as it applies to space objects. One of them is the technical one, due to the possibility of malfunction of equipment as a result of reproduction of microorganisms on the materials. The other aspect, which has not been given adequate attention thus far, is the medical one. It is related to the possibility of involvement of conditionally pathogenic microorganisms, representatives of human automicroflora, in processes of destruction of polymer materials. There is reason to believe that reproduction of potential pathogens of infectious diseases on polymers, even before malfunctions appear in the operation of various equipment, would present an epidemiological and toxicological hazard to the health of cosmonauts, and this circumstance merits attention.

General [or home] sanitation is one of the parts of residential and communical sanitation and, as it applies to people in spacecraft, it can be viewed as a set of measures aimed at meeting the personal hygiene requirements of cosmonauts, as well as maintaining optimum general conditions, including also subsequent preservation or processing of human waste, periodic cleaning of quarters, regular removal of dust and microorganisms from the air.

The overall general sanitation provisions for the system of personal hygiene, or more precisely, the equipment used for this purpose, can be discussed in the historical aspect as systems of different generations, according to complexity and volume of means used. Systems of personal hygiene used aboard the Vostok, Voskhod, Soyuz, as well as Mercury, Gemini and Apollo spacecraft, can be classified as

the first generation. The missions aboard these spacecraft were short (the longest lasting 18 days for Soyuz-9), and at the same time there were strict restrictions as to size, volume and power. For this reason, cosmonauts and astronauts used dry and wet washcloths and towels for personal hygiene.

The personal hygiene system developed for the Skylab and Salyut-6 program, which constituted second generation systems, were not strictly limited in mass, volume and power. However, even in this case, moist washcloths and towels were used by cosmonauts and astronauts to wash themselves. A "shower" was selected to keep the body clean, which the cosmonauts and astronauts could use periodically. It must be noted that the crew of the third mission aboard the Salyut-6 orbital station took showers about once a month, while some astronautics took showers sporadically aboard the Skylab orbital station.

The measures for oral hygiene consisted of brushing the teeth with a brush and toothpaste and chewing gum after meals.

Extending manned space flights (as was the case during the work done by the crews of the second and third missions aboard Salyut-6 orbital station) imposes special requirements with regard to sanitation and, in particular, personal hygiene. In view of the need for cosmonauts to wash in the course of long flights, special attention must be given to the choice of appropriate fabrics for dry and wet cloths and towels that are to be reused. The main purpose of these items should be not only to keep the body clean, but an antimicrobial effect directed toward stabilizing the quantitative and species-related composition of the cutaneous microflora within the range inherent in healthy people. Analogous requirements should also be made with respect to cleansing agents recommended for use in showers. Studies dealing with evaluation of possibility of habituation of human automicroflora to the recommended antimicrobial agents are considered promising. This factor must be included in the requirements made of disinfectants that are proposed for use in a spacecraft cabin.

One of the main tasks in developing the set of measures for sanitary support is to conduct broader sanitary and hygienic, as well as physiological, studies in order to obtain evaluations of the functional state of the integument and external mucous membranes of people during space flights.

In conclusion, it must be stated that we tried not only to sum up some of the results of sanitary-hygienic studies here, but to mention the problems, which are the most pressing ones in our opinion, that must be resolved within the framework of the task of creating good living conditions aboard spacecraft that will function for long periods of time.

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OPTIMUM ATMOSPHERE IN PRESSURIZED CABINS AND FUTURE USE THEREOF

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[Article by N. A. Agadzhanyan, submitted 22 Oct 80]

[English abstract from source] Physiological validation of an artificial atmosphere in manned cabins of flying vehicles remains to be one of the major biomedical problems. It has been experimentally demonstrated that oxygen and carbon dioxide are closely related in vital processes, acting as antagonists or synergists. Changing their content in an enclosure, it is possible to influence the function of the human body and to correct its deconditioning due to prolonged hypokinesia. Active mountain adaptation accompanied by a marked mobilization of physiological systems seems to train and activate functional reserves of the body, making them more adequate to tolerate extreme effects.

[Text] The question of physiological substantiation of the principles involved in forming the artificial atmosphere in the cabins of manned flight vehicles is still one of the most important and interesting ones. This is understandable, if we consider that the advances in the conquest of space are inseparable from the coordinated solution of basic biomedical and scientific technological problems.

The problems that arise when selecting the atmosphere for sealed cabins include many aspects, namely: determination of the effect on the body of high and low O_2 and CO_2 levels, air temperature, tolerance of rapid decompression, caisson disease and others. In turns, all of these physiological problems are closely interwoven with engineering requirements of paramount importance, such as regulation of parameters of the microclimate, circulation of gas, operation of the system of atmosphere regeneration, maximum reduction of craft mass, power consumption and leakage of gases from the manned cabin, fire safety, etc.

In view of the increase in duration of space flights, the time spent in such miss[illegible] crews will be limited primarily by human endurance, i.e., physiological aspects related to man's being in the unique conditions of sealed compartments of limited size, rather than by technical capabilities and stock of material resources.

The atmosphere that is created in the sealed cabins of Soviet spacecraft has parameters that are similar to those of the earth's atmosphere. However, it would be

wrong to believe that one could select a gas environment equally suitable for any flight conditions for spacecraft and extraterrestrial stations of the future. Simulation of earth's atmosphere in sealed cabins intended for long stays by people in a new habitat environment--altered gravity--is a simple, but hardly optimum and scientifically justified solution. From the standpoint of fire safety, prevention of the toxic effects of O_2 and endurance of high temperatures, the earth's atmosphere is best. But such an atmosphere is the least favorable in the case of rapid decompression, as well as extravehicular activity (in such an atmosphere the body is highly susceptible to the bends).

The question of possiblity of using single component oxygen environment in spacecraft is also debatable. A monogas environment has a number of advantages over a single-component one [sic], and therefore it has attracted the attention of designers and physiologists. However, such a gas environment also has some serious negative aspects: it harbors the danger of atelectases of the lungs, it is a fire hazard, etc. In addition, it is still not clear whether the organism can exist for a long time and develop in an atmosphere wanting in nitrogen or whether this gas has an important bearing on intimate physiological processes in the body.

Prolonged exposure to a nitrogen-free atmosphere elicits substantial biochemical, immunological and pathomorphological disturbances in the organism, with damage to tissular enzymes that take care of the energy requirements of cells.

Studies must be continued of different variants of gas environments in the interests of finding broader technical and biological opportunities for supporting human life in space [1-4].

In searching for an artificial atmosphere for sealed cabins of space flight vehicles, in addition to knowledge about the main patterns of evolutionary development of living beings on our planet and ecological-physiological distinctions of the new habitat, it is imperative to consider the fact that the future development of cosmonautics will be directed not only toward prolonging space flights, but active development of world space. Consequently, biomedical problems of space flights, in particular the problem of forming the artificial atmosphere of pressurized cabins, must be considered from the standpoint of preserving satisfactory living conditions and active performance by man in his new habitat. Continued studies of the patterns of functional, morphological and biochemical changes in the body in the new habitat must be considered the important aspects of investigation of problems of adaptation of man and animals to altered gas environments.

In the course of evolutionary development, the organism developed an orderly system of specialized physiological systems to maintain stability of the endogenous environment; these systems themselves (to main high efficiency) require regular conditioning, a constant functional load. Otherwise, decondition develops and general resistance of the body diminishes.

Thus, activity and intensive function of structures as vital biological stimulators of their development and refinement are, at the same time, an important physiological constant for proper adaptation of the entire organism to a new habitat. This is why the problems of choosing an optimum gas environment in pressure chambers, as they related to man spending a long time with limited motor activity and in weightlessness, should be considered from the standpoint of desirability and

importance of using functional exercises in order to prevent deconditioning of the body.

Since the first space flight of Yu. A. Gagarin, numerous studies by Soviet and foreign authors demonstrated that there is a decrease in minute respiratory volume O_2 uptake, CO_2 output, basal metabolic level, blood pressure, stroke and minute volume of the heart, negative nitrogen balance and diminished muscle mass volume, as well as decrease in plasma and erythrocyte volume, slower glycolysis and drop in myoglobin content, in the presence of hypokinesia and weightlessness, and when man spends a long time in small sealed chambers. When the bone marrow is inactive, there is also a decrease in production of erythrocytes, circulating blood volume and its oxygen capacity, with increased accumulation of catecholamine products in the myocardium; impaired coronary circulation is observed, as well as increased elimination in urine of elements such as Na, K, Ca, S and P. Under such conditions, orthostatic hypotension, diminished efficiency [or fitness] and resistance to some extreme factors were also observed.

Until recently, the main methods of correcting disturbances arising under hypokinetic conditions and in weightlessness amounted to the use of a special set of exercises and drugs, creating pressure over different parts of the body. In the last few years, there was physiological substantiation of the hypothesis that an altered gas atmosphere can be used as a preventive agent when deconditioning develops [1, 3].

The studies which we conducted for many days in habitable pressure chambers of small size, as well as in the mountains under natural conditions, revealed that adaptation to O_2 shortage elicits changes in the body that are the opposite of the reactions to hypokinesia and wieghtlessness. With long-term conditioning for moderate hypoxia there is enhancement of the body's resistance to the set of extreme factors such as acute hypoxia, accelerations, heavy physical loads, high temperatures, etc. It was demonstrated that the enhanced resistance of tissues after adaptation to hypoxia was associated with stimulation of processes of energy metabolism, accumulation of biologically active substances and increased erythropoietic activity. Activation and increase in number of mitochondria per unit cell mass is a consequence of adaptation to hypoxia. Moreover, the studies of a number of authors revealed that hypoxia elicits about the same physiological changes in the body as with physical training. In both cases, there is similar functional change in the main regulatory systems of the body. It is known that development of adaptational changes in a new habitat is based on processes that take place on the tissular level. Ultimately, the increase in strength of the energy system and activation of reserve capabilities of the integral body determine the effectiveness of adap ation to different factors.

Since O_2 plays an important role in energy processes, there is reason to believe that any changes in oxygen conditions in the body that are in the same direction would lead to the same end result.

CO_2, as the end product of biological oxidation, is equally important to the body's respiratory function.

We know that the overall reserve of O_2 in a man weighing 70 kg constitutes only about 2-2.5 ℓ, with no less than 50% of the total reserve referable to blood O_2. When scaled to the unit of body mass, the O_2 reserve in the human body constitutes

about 0.025 ℓ/kg. The physical distinctions of the O_2 molecule and its excessive activation probably did not make it possible to develop, in the course of evolution, a system that would retain a supply of O_2 in the body for a long period of time.

The situation is different with regard to deposition of the other respiratory gas, CO_2. The overall supply thereof in the body constitutes 120-125 ℓ, which corresponds to about 1.8 ℓ per kg body mass. The store of CO_2 in the body depends on the volume and buffer capacity of noncarbonate buffers and pCO_2 in tissues. And while CO_2 is contained mainly in body tissues, the reserve of O_2 is present mainly in the lungs and blood.

In the physiological validation of parameters of the gas atmosphere of pressure cabins, it is of practical importance to define the maximum permissible CO_2 concentrations in the cabins of flight vehicles.

Some researchers believe that the atmosphere of sealed compartments must have no CO_2 at all, while other specialists recommend the use of a CO_2 excess for regeneration of O_2 in photosynthetic systems, for the prevention of hypocapnia that occurs in some flight situations, and even to attenuate the deleterious effect of cosmic radiation. All this makes it imperative to pursue studies to set the maximum permissible concentrations of CO_2 for brief and long stays in small sealed chambers. It was demonstrated that the time factor has its own biological significance. Prolonged (up to 30 days) exposure of people to an atmosphere with high CO_2 content (up to 7.6 mm Hg) had no appreciable effect on general condition or fitness of subjects. Under the same conditions, but with further elevation of pCO_2 in the sealed chamber, there was gradual accumulation in blood of both free and chemically bound CO_2 to levels inherent in hypercapnia [5].

In other words, so long as the concentration of CO_2 in inhaled air is lower than alveolar, hypercapnia is compensated to a significant degree by the ventilatory reaction. But with prolonged exposure to such conditions, adaptive regulation of the cardiorespiratory system may be impaired and cause elevation of pCO_2 in blood and tissues.

The marked compensatory reactions of the body observed at the early stage of exposure to an altered gas environment are achieved at too great a price, and they are related primarily to large expenditure of energy for intensive hyperventilation. While the work of skeletal muscles constitutes 0.56 kg-m/min during calm breathing of air, it increases under the influence of hypercapnic mixtures in conformity with pCO_2, proportionately to the logarithm of ventilation with an exponent of 1.79 [2, 6, 7].

After 5 days in an atmosphere with high carbon dioxide content (pCO_2 38 mm Hg), diminished resistance of man to acute hypoxia, transverse accelerations and heavy physical loads was observed.

The same studies revealed that if, in a hypercapnic gas environment, pCO_2 of alveolar air increases to more than 45 mm Hg there is virtually complete blocking of the pulmonary mechanism of elimination of CO_2 from the body, as a result of which there is accumulation in the lungs of endogenous CO_2 and absorption of exogenous CO_2 from the inhaled gas mixture. This is associated with intensive compensatory elimination of hydrogen ions through the kidneys, which is directed toward

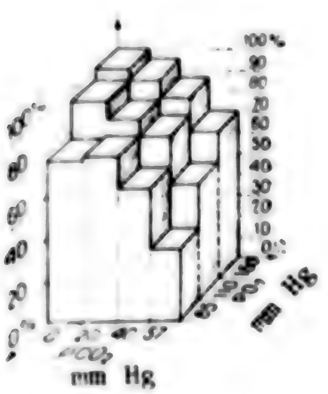
maintaining the levels of blood bicarbonates and is associated with significant polyuria and elimination of Na. Under such conditions, even light physical work is performed with greater tension, and it is associated with more marked tachycardia, arterial hypertension, intensification of headache and dyspnea.

Interestingly enough, in the aftereffect period one observes distinctive "disappearance" of part of the CO_2 accumulated in the body. This can be attributed either to blocking of the mechanism of CO_2 production, or temporary adsorption thereof by tissues, or else, finally, by triggering of other extrapulmonary compensatory mechanisms directed at maintenance of stable pH of the medium [2, 8].

The results of complex physiological studies revealed that such biologically active gases as O_2 and CO_2 interact very closely during body functions, and they may emerge as antagonists and synergists. One can deliberately influence the functional state of the body, provide a constant functional load and activation if the main compensatory systems, and thereby correct signs of deconditioning that appear when one is submitted to long-term hypokinesia by altering such extremely important parameters of the atmosphere as pO_2 and pCO_2 in habitable sealed chambers of small size.

The best effect was observed in an "active" dynamic atmosphere, which was cyclically altered over a 24-h period, with gas environment parameters of 125-115 mm Hg pO_2 and up to 5 mm Hg pCO_2 in the daytime, and 105 and 10 mm Hg, respectively at night, combined with moderate exercise. Total pressure constituted 405-760 mm Hg in different studies.

Cyclic fluctuations of the main respiratory gases stimulate the cardiorespiratory system and glucocorticoid function of the adrenal cortex, and thereby attenuate the adverse effect of hypokinesia. The changes in the blood clotting system in the direction of hypocoagulation, which arise in the presence of moderate hypoxia, revert to normal with addition of CO_2. Periodic addition to the atmosphere of a habitable chamber of CO_2 (to 10 mm Hg) is an important means of preventing hypocapnia.



Physical fitness (% of base level) when breathing gas mixtures with different amounts of O_2 and CO_2.

Mean value of physical exercise performed in a control series of studies was taken as 100%.

Our studies demonstrated a correlation between the gas environment and tolerance of extreme factors. The obtained data indicate that there is expansion of reserve capabilities of the main functional systems and body as a whole as a result of the stimulating effect on the body of an "active" atmosphere. Decline of systemic resistance and efficiency of the body is observed in an atmosphere with excessively high CO_2 level.

It was demonstrated that the CO_2 level in inhaled air is a factor that determines the dynamics of decline of fitness when breathing gas mixtures with 160-80 mm Hg pO_2 and 20-57 mm Hg pCO_2 (see Figure). It was also established that the level of physical fitness progressively declines with increase in hypercapnia. After changing from breathing hypoxic-hypercapnic gas mixtures to atmospheric air, restoration of gas exchange occurs within about 30-40 min. In this time, up to 4 ℓ bound CO_2 is eliminated from the body [5, 8].

Although modern flight vehicles are equipped with reliable means of protecting man from deleterious environmental factors, one cannot rule out entirely the possibility of leakage of atmosphere from the habitable cabin, as well as partial or complete malfunction of life support systems, which could lead to a drop in pressure and change in O_2 and CO_2 content in the cabin's atmosphere. The rate of change in the main respiratory gases would then be proportionate to the intensity of gas exchange and inversely proportionate to the volume of the pressurized cabin.

An acute shortage of O_2 is the most dangerous. Under such conditions, it is very important to determine the order of development of functional disturbances in the entire body and the weakest links in metabolism. It is known that most of the O_2 consumed by the body is used for oxidative phosphorylation. Adenosine triphosphoric acid (ATP) is the main reserve of energy for cells; it is used for chemical synthesis of substances, muscular contraction, regulation and other processes. Tissues of the brain, heart and kidneys are the chief consumers of energy. Suffice it to mention that brain tissue takes up about 25% of all O_2 inhaled by man. What then are the chief mechanisms of development of functional disturbances when there is an O_2 shortage? Under these conditions, first of all there is a decrease in concentration of ATP. For example, with an acute shortage of O_2, ATP content of brain cells decreases by about 50%. Along with a shortage of energy, there is accumulation in cells of incompletely oxidized products, and blood acidosis is observed. In turn, this causes a significant change in activity of cellular enzymes, and their bonds with membrane structures are impaired. Biosynthesis of hormones and neuromediators is impaired in the presence of acute hypoxia [9].

Prolonged adaptation to moderate hypoxia, for example in the mountains, curbs these disturbances to some extent and enhances systemic resistance.

In order to comprehend the physiological mechanisms of hypoxic disorders and to work out preventive measures to assure the safety of space flights, it is imperative, first of all, to investigate the physiological mechanisms of adaptation to hypoxia. Numerous studies have shown that, in the complex system of adaptation to hypoxia, various levels of intercoordinated adaptational mechanisms are directed toward assuring adequate access of O_2 into the body (primarily to such vital organs as the brain, heart and kidneys), as well as increasing the tissues ability to utilize O_2 from blood and, in spite of hypoxemia, to form ATP. Some researchers include the increase in anaerobic resynthesis of ATP as a result of activation of glycolysis among the important adaptation mechanisms [10].

In the presence of acute hypoxia in accident situations, one should reduce to the utmost degree the energy expenditure of tissues, as well as intensity of metabolic processes in cells in order to prolong life as much as possible. The tactics must be quite different in the case of chronic hypoxia. It is known that, at the early stage of adaptation to hypoxia, the syndrome of mobilization and hyperfunction of transport systems is usually associated with signs of functional insufficiency

and reduction of general fitness. As adaptation progresses, hyperfunction of transport systems, which is energy-wasteful and ineffective, and which is observed at the emergency stage, is followed by relatively stable adaptive changes on the tissular level. As a rule, at this time, the slight hyperventilation and hyperfunction of the heart occur against the background of rather high efficiency of the body. The stage of stable and effective adaptation to hypoxia may be followed by a stage of depletion of adaptational capabilities. As adaptation to an alpine climate progresses, one observes a decline of threshold of sensitivity of the respiratory center to a hypercapnic stimulus. The body's ventilation reaction to hypercapnia increases constantly. Active adaptation to the mountains, which is associated with frequent and more noticeable mobilization of physiological systems, so to speak conditions and activates the functional reserves of the organism, renders them more labile and more perfect for endurance of high concentrations of CO_2 and other extreme factors.

The findings are more complex when there is malfunction of the system for regenerating the atmosphere of a habitable pressurized cabin, i.e., when there is concurrent increase in hypoxia and hypercapnia. Our studies demonstrated a correlation between changes in physiological systems of the body, time that efficiency was retained and maximum time a man could spend in such a cabin, on the one hand, and the nature of malfunction in the life support system, rate of progression of hypoxia and hypercapnia, and maximum pO_2 and pCO_2 levels in the pressurized chamber.

With normal CO_2 content and progressive drop of pO_2 in the chamber atmosphere at rates of 10 mm Hg every 15 and 240 min, the reserve time of preservation of fitness constituted 2.6 and 34 h, respectively, and maximum pO_2 constituted 60 and 74 mm Hg. With concurrent increase in hypoxia and hypercapnia in the atmosphere of a habitable pressurized cabin, the cardiorespiratory system experiences greater functional tension and, even in the presence of adequate oxygenation, it does not relieve the organism of the state of decompensated respiratory acidosis in blood, which leads to diminished fitnesss [8].

The level of physical fitness drops to a greater extent when there is concurrent increase in shortage of O_2 and excess CO_2 in the habitable sealed chamber than under the separate effect of hypoxic or hypercapnic gas atmospheres. The only exception was when carbon dioxide with pCO_2 of 20 mm Hg was added to hypoxic gas mixtures with pO_2 of 85 mm Hg. Numerous pressure chamber tests established that, in emergency situations in a habitable cabin, with malfunction of the systems for regeneration of the atmosphere, drop of pO_2 to 85 mm Hg and elevation of pCO_2 to 57 mm Hg, man can perform only 30% of the exercise that he is capable of performing under normal conditions.

On the basis of laboratory studies, a nomogram was proposed and adopted for determining man's reserve time with elevation of pCO_2 and drop of pO_2 in pressurized cabins.

A dynamic gas environment, with overall pressure of about 405 mm Hg, pO_2 105-125 mm Hg and $pCO_2 \leqslant 10$ mm Hg, was recommended for habitable cabins of flight vehicles in order to enhance general reactivity of the organism, improve tolerance of acute hypoxia, accelerations, heavy physical loads and for the prevention of decompression disorders.

Cyclic fluctuations of parameters of the gas environment must conform with the work and rest schedule of the crew. When heavy physical work is performed, pO_2 and pCO_2 in the pressurized chamber must be held at normal levels.

The experimental data obtained from long-term studies of man and experiments on animals made it possible to provide scientific substantiation for the hypothesis that one can deliberately alter systemic reactivity, eliminate deconditioning and preserve fitness at a rather high level by altering the composition of the atmosphere and having the gas environment conform with the work regimen and energy expenditures.

It is unquestionable that persistent and well-planned research on this extremely important biomedical problem will result in development of scientifically substantiated measures to form the optimum gas environment in pressurized cabins.

The scientific principles that evolved from 20 years of practical Soviet cosmonautics, as well as good theoretical and technical implementation of biomedical research, create every opportunity for successfully solving pressing scientific and practical problems.

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FITNESS OF HUMAN VISION WITH EXPOSURE TO VERY BRIGHT LIGHT

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[Article by V. I. Kartsev, submitted 30 Oct 80]

[English abstract from source] The review survey publication on visual reactions of man pre-exposed to the deadaptive effects of different light sources and discusses perspective lines of research.

[Text] In the last 20-25 years, researchers have been faced with more and more new problems, which are related to visual fitness of pilots and cosmonauts when exposed to extremely bright light sources. Successful work with control systems and various instruments, observation of surrounding space and earth's surface depend largely on the functional state of the visual analyzer of the crew, as well as a number of environmental factors, which also include unusual illumination. It has been established that, even with a very rapid glance at the sun with the naked eye or with inadequate protection, a cosmonaut may sustain serious retinal burn, which causes partial loss of visual field, i.e., scotoma [1]. Analogous eye injuries were observed among Japanese fishermen who were in the Pacific Ocean during an explosion of an atomic bomb. Mushroom-shaped cicatrices were found on their retina.

Quite often, along with problems related to function of the visual analyzer, researchers also solve problems of protecting it. Having studied the functional state of the visual analyzer following a nuclear explosion, Hill and Chisum [2, 3] observed that protective glasses did not have sufficient optical density to protect the eyes. Moreover, it is impossible to use them for many types of work, because of the high optical density of filters. Other protective devices also failed to meet the necessary requirements. Temporary blindness after exposure to light due to nuclear explosions does not present an immediate threat to the visual analyzer, but it may be dangerous to individuals who control equipment and could lead to an emergency situation or failure to perform the needed task [4, 5].

The following data give us some idea about the range of brightness within which the human eyes function.

A white surface illuminated by direct solar rays or snow under good solar light may have a brightness of 2.5-3 stilbs (sb), which corresponds to illumination of 100,000 lux on a white background. The top optimum range of illumination for the human eye is 200 lux on white. Brightness close to 32.5 sb is blinding at all

levels of light adaptation [6]. The brightness of the sun's surface visible through earth's atmosphere is 147,000 sb. However, the negligible angular dimensions of the sun and attenuating effect of the atmosphere protect the eye from injury. The visual analyzer is able to detect extremely weak photic stimuli also. Thus, a white surface illuminated by the moon has a brightness of about $6 \cdot 10^{-6}$ sb. Stars of the sixth magnitude, which are on the boundary of visibility with the naked eye, create about $8 \cdot 10^{-9}$ lux illumination on earth. Under ideal conditions, it is possible to see the flame of a candle at a distance of 27,353 m [7].

Most of the time, pilots and cosmonauts are exposed to brightness of up to 3.5 sb. This is quite tolerable for the visual analyzer, but when brightness fluctuates in this range some time, perhaps a lengthy period, may be required for readaptation. This period depends on the level of eye adaptation, brightness and size of the light source, duration of light adaptation, etc. And the pilot of a modern aircraft may not have enough time for the eyes to adapt to an altered level of light.

Determination of the time after temporary blindness, within which the pilot could not take readings from the gyro-horizon and altimeter, as well as studies of visual acuity with Landolt rings, revealed that the time of restoration of vision after a flash of light constituted a mean of 13.6 s with console illumination of 0.5 cd (about 5 lux). A jet aircraft flying at a speed of 1800 km/h would travel "blind" in this time over a distance of over 7 km. The speeds of the latest aircraft and spacecraft are considerably higher, while the time of visual adaptation may be measurable in minutes, rather than seconds as in the above example. This could also apply to the operators of high-speed ground and maritime transport It should be added that the power of a light source, particularly aboard spacecraft, is limited, and for this reason one cannot increase sufficiently the illumination of panels and other displays that are needed for the crew's work, in order to partially compensate for deadaptation.

Before we discuss restoration of photosensitivity after exposure to bright light, let us briefly review its history.

First of all, we must mention the study and determination [9, 10] of the magnitude of minimal blinding brightness as a function of brightness of the field of vision, which is expressed by the formula:

$$G = 8\sqrt[3]{B} \text{ (in stilbs)}, \quad G = 1700\sqrt[3]{B} \text{ (millilamberts)},$$

where G is the minimal blinding brightness and B is the brightness of the field of vision. The absolute blinding brightness for central vision, whatever the state of retinal adaptation, was determined by means of this formula. This brightness equals 22.4 sb with angular dimension of the light source of about 4°.

Holladay [11] singled out the factors determining the blinding effect of a light source. They include the following: power of light, brightness, spectral composition, distance to the eye and size of glaring source, its position in relation to the visual axis; shape, size, distance and reflecting properties of the object; brightness of adaptation background and its contrast in relation to viewed object; state of adaptation, pupil size, accommodation, contrast sensitivity. The author derived a formula reflecting the link between subjective sensations arising during exposure to a blinding light source, mangitude of the blinding source and brightness of adaptation field.

The broad aspect of this problem drew the attention of many researchers. Thus, [illegible] [12] submitted extensive data dealing with the study of functional capacity of the visual analyzer, hygiene of vision, adaptation of central and peripheral vision. The same issues were discussed in the book, "The Eye and Its Function" [13]. The authors' objective was to make a direct study of physiology of the visual analyzer under extreme conditions; however, they made a significant theoretical contribution to the practical solution of this problem.

A work [14] shedding light on many problems of ophthalmology, which also submits a classification of blindness, is referable to a later period.

We should also mention research dealing with narrower aspects of the problem of restoration of light sensitivity after being blinded. Thus, it was established that recovery time for light sensitivity increases with increase in brightness of the light source. Lamps of up to 500 W were used for 15 min [15].

The nature of the relationship between adaptation, power, localization and area of light after very bright flashes was demonstrated. Virtually point light sources were used [16-19].

Studies of correlations between the center and periphery of the retina during exposure to intensive photic stimuli demonstrated the reciprocal mutually inhibitory influence of photopic and scotopic systems [20, 21].

Many studies dealt with the blinding effect of signal lights. Among these, we were impressed by works [22-23] that demonstrated that with increase in brightness of the adaptation field, the influence of glare diminishes and that contrast sensitivity depends expressly on glare more than other visual functions. According to the data in [24], the time of recovery of contrast sensitivity increases with increase in brightness, duration of exposure and size of the glaring source.

Fitness of drivers subject to sudden blinding light is discussed in [25, 26].

The blinding effect of a stationary light source was studied comprehensively by Sokolov [27]. In his experiments, exposure time ranged from 1 to 10 s, with angles of exposure to glare ranging from 4 to 40° and 0.1 to 1000 lux blinding illumination of the pupil. It was established [28] that glaring and constant signal lights have the same blinding effect on an operator.

Much attention has been devoted in the literature to questions of the blinding effect of a light source as a function of wavelength. It was noted [29] that a sodium-vapor lamp has a less blinding effect than incandescent and mercury lamps, the blinding effect of which is the same. As we see, authors have arrived at opposite conclusions. This shows that this problem has not yet been definitively resolved.

It was also established [31] that, of the colored flashing lights, the most blinding effect is caused by green, followed by white, yellow and red.

Some correlation was demonstrated between the blinding effect and color (white, blue, green and red) of a flashing [or glaring] source [32].

Measurements [33] revealed that a flashing signal from a red glaring light source has a less blinding effect on discriminatory sensitivity of the eye that light from an incandescent lamp with T_{ya} = 3200°K ["ya" probable refers to brightness]. White, yellow and green flashing lights have virtually the same blinding effect, but it is much stronger than red [34]. Visual acuity diminishes the least and is restored the quickest to its base level after brief (0.001 s) exposure to an intensive (100,000 lux to the pupil) flash of blue light [35].

Studies were made of the effect of intensive photic stimuli (3000 lux at eye level) on color sensitivity after 10 min of exposure [36]. A record was made of the time of recovery of color sensitivity to recognition of red and green by the subjects, and a color equation was solved. From 50 to 130 s were required for total restoration of color perception. The author believes that this could have a serious effect on the performance of a pilot when time is extremely short.

A study of the causes of loss of a light aircraft with colored front windshiled (which absorbed 34% of the rays in the visible part of the spectrum) during a night visual flight included analysis of the possible situations preceding the accident under simulated flying conditions. Studies were made of the rate of visual adaptation without light in the cockpit, with a constant level of illumination and after switching off the map light. The author concluded that coloring the windshield of an aircraft presents a hazard during visual flights at night.

The above-mentioned studies dealing with the effects of color on adaptability of the visual analyzer appeared to offer to physiologists and designers an opportunity to organize the work process for pilots and cosmonauts. However, analysis of the visual work of an operator, with the use of different color filters and combinations thereof [38] revealed that color discrimination is lost with a red or other bright color and there is a complete change in correlation between color brightnesses. This limits the use of "color" in the work of pilots, cosmonauts and operators of high-speed transport. The authors recommend brightness ranging from ~0.1 to ~220 lux against a white background for displays, instrument panel and map lights.

Illumination of the human eye (in the range of $2.5 \cdot 10^3$ to $50.0 \cdot 10^3$ nit) diminishes color and brightness contrast sensitivity, as well as the functional stability of color discrimination, and it causes temporary loss of color discrimination [39, 40].

Theoretical consideration and studies in simulators made it possible to determine the illumination for the cabins of the Apollo spacecraft [1]: about 1500 lux for signal indicator lights, about 200 lux (average) and 400 lux (maximum) for the instrument panel, control console and work zone. Moreover, it was established that the illumination in the cabin during accelerations after launching a spacecraft and braking when entering the dense layers of the atmosphere must be twice the normal level, since visual fitness of cosmonauts worsens at these times. Thus, the magnitude of illumination cannot be constant. What is the required range of brightness so that the cosmonaut can rapidly take readings from displays? It was noted [38] that cathode-ray tubes are good for delivering information. The capacity to see a target is not significantly affected if the brightness from a cathode-ray tube does not exceed the mean brightness of the screen by more than 100 times. In other words, if the cosmonaut has to observe the daytime sky (brightness of about 100,000 lux on white), the mean brightness of the screen, required for rapid reading, should be ~1000 lux on white, or more. By arbitrarily extrapolating these

results to work aboard the Apollo spacecraft, it is not difficult to become convinced that, after observing the daytime sky or other object illuminated similarly (100,000 lux), the cosmonaut will not be able to receive rapidly the necessary information from the instrument panel, control console or in the work zone, since their illumination would not exceed 400 lux, instead of the required minimum of 1000 lux. Only signal displays have adequate illumination (1500 lux) for rapid visual reading of information. However, as mentioned above, in some situations the crew will encounter a brightness level significantly exceeding 100,000 lux on white. Apparently, under such conditions, the range of brightness in the work zone of an operator should be such as to be able to read the displays virtually instantaneously.

It has been shown [41, 42] that the increase in adaptation time of central vision is proportionate (up to a certain level) to the increase in the adapted area. It was established that adaptation of the visual analyzer depends on the localization of the effect on the retina of a deadapting bright flash.

Analysis of these works revealed that the studies were conducted for the purpose of solving specific practical problems, both with regard to methodology and organization. For example, to solve problems of light signals, the authors had to test the effects on the eyes of a virtually point source, but very bright light source in the form of flashing or constant signal light; for development of hygiene of vision as related to different types of work, they had to study optimum illumination conditions for the work place, location of light source in field of vision, etc.

At each successive stage of development of technology, there was an increase in demands made of operators, in particular, of their visual fitness. For this reason, the experience and results of prior studies made it possible to solve newly emerging problems.

In the past 10-15 years, there was delineation of the means of evaluating the effects of high levels of brightness on adaptability of the visual analyzer. Thus, in a survey of the literature dealing with mechanisms of "blinding" from brief extrabright flashes of light [43], it is noted that, in the opinion of a number of authors, the role of photochemical processes in the retina depends on exposure time and brightness of the light source. It was also shown that there could be a deviation from the psychophysiological law of Bunsen-Roscoe, who established a constant correlation between the degree of decline of light sensitivity and product of intensity of stimulus multiplied by duration of exposure to it (for point light sources), under the influence of brief extrabright flashes.

In their studies of recovery of light sensitivity after exposure to a photic stimulus under different conditions, researchers emphasize in one way or other that enhancement of sensitivity of the light-receiving system is a function of brigbtness and time of exposure. Thus, the time of recovery of the threshold of light perception is a function of brightness and duration of a flash [44]. In that study, exposure time constituted 0.1 and 1.0 s, brightness constituted 160 and 1600 mL for the light and 0.01 mL for the adaptation background. Recovery time did not exceed 4 min.

The time of recovery of central visual sensitivity diminishes with increase in angular dimensions of the test (Landolt ring) and brightness of adaptation background

(from $1.9 \cdot 10^{-4}$ to $1.9 \cdot 10^{-2}$ nit), but increases with increase in amount of illumination (to 15,500 candle-second) generated by the flash on the observer's pupil [45].

A 10-ms flash was used in [46], with illumination at eye level of 60 to 12,000 lm/m^2 and illumination of instrument panel of 0.07 lm/m^2. Recovery time constituted 6 to 108 s. There was negligible increase in color sensitivity after exposure to flashes generating a light flux of over 1000 lm/m^2.

It was found [2, 3] that the time of recovery of light sensitivity after exposure to a flash (lasting 33 to 165 μs and 9.8 ms, maximum brightness 7.1-8.6 log L, angular dimension 10°) diminishes with increase in illumination of the adapting object and increases with increase in time or brightness of the flash. The authors observe that these conclusions are suitable for a limited range of parameters. A study was made of the effect of pupil diameter on rate of recovery of light sensitivity [47, 48]. A correlation was demonstrated between time of recovery of light sensitivity and amount of light energy reaching the retina.

Thus, the results of these studies revealed that the magnitude or time of visual reaction is determined by the energy of the photic stimulus, which is the product of the active light factor multiplied by the time of exposure to the stimulus (other conditions being equal). However, the used combination of levels of photic stimulation and exposure time could vary for different authors. The patterns of visual reactions could also, apparently, differ.

V. I. Kartsev [49] studied recovery of visual acuity after temporary blindness caused by prolonged light adaptation to a white screen exposed to the sun or illuminated with an incandescent lamp (the parameters of the photic stimulus corresponded approximately to the working conditions for an operator on a clear sunny day). The results of these studies revealed that there are two factors that determine the time of recovery of visual acuity after exposure to blinding light: the energy of the photic stimulus in lux-seconds and level of adapting background brightness of the test table. A change in time of recovery of central visual acuity is a function of energy of blinding light according to an exponential law up to a certain magnitude of the photic stimulus. Then the curve is virtually horizontal, which is indicative of stabilization of the reaction of the visual system to the effect of a blinding stimulus increasing in power. A 2-4-fold increase in power of the stimulus in this range does not alter the time of restoration of sensitivity of visual acuity.

It must be stressed that similar results were obtained in [38] in a study of adaptation of central vision after exposure to light with delivery of visual information using a cathode-ray tube. The authors observed the following: 1) if the visual system is exposed to relatively high brightness it becomes stable after a certain time, i.e., light sensivity reaches a "plateau"; 2) if the eye is exposed to brightness of 2000 mL (the birghtness of daylight) for 15 s ($15 \times 2000 = 30,000$ mL/s), it loses sensitivity equivalently to an eye exposed to 200 mL for 150 s ($150 \times 200 = 30,000$ mL/s); 3) the ability to see is not worsened if higher brightness levels do not exceed the mean brightness of the tube screen by more than 100 times. However, the question of adaptation time for central vision if this difference exceeds 100-fold and how this parameter is to be found was not discussed by the authors.

The results obtained by V. I. Kartsev [49] describe the time of recovery of visual acuity after a stronger photic stimulus exceeding the brightness of the test table by 5000-100,000 times. On the whole, however, it must be stressed that, when

working with a cathode-ray tube in a different range of brightness [38], Morgan et al. demonstrated patterns that reinforced well the data and conclusions of V. I. Kartsev [49]. This expands appreciably the opportunities for applying the results obtained by both authors.

We should recall that measurement of light sensitivity of the human visual system after exposure to a photic stimulus had been performed previously by other researchers also.

Thus, it was found that the time of recovery of the color-perception threshold is a function of brightness and time of the deadapting flash [44]. It was also demonstrated that peripheral dark adaptation after a flash depends only on the amount of light and not its brightness (in the tested range of brightness and duration of blinding) [50]. It was demonstrated that the time of adaptation of visual acuity after exposure to light is a function of the product of brightness multiplied by time [51]. It was established [52] that the power of flashes is a factor that determines restoration of light sensitivity of the human eye after exposure to these flashes. The nature of the functions changes with reduction of duration of flashes.

The results of the studies indicate that the parameters of the photic stimulus determine the time of recovery of sensitivity of both central and peripheral vision. This pattern is present in recovery of light sensitivity after both a flash and prolonged exposure to light. However, it should be borne in mind that the recovery time for visual functions changes, as shown by the results of the abovementioned authors' studies, as a function of brightness of deadapting light, exposure time and brightness of the background of the test stimulus.

Some authors reported stabilization of recovery time of light sensivity after a certain magnitude of deadapting photic stimulation. For example, V. I. Shostak [53], who studied recovery of discriminating function of the eye after exposure to blinding bright light (flashes), expounded the hypothesis that there is a "critical" point, after exceeding which further increase in brightness of the stimulus no longer leads to appreciable delay in recovery of discrimination. However, we did not find any mention in the literature of the fact that the time of recovery of visual acuity could remain unchanged when the photic stimulus is increased by 2-4 times, with prolonged exposure to light. Perhaps, this circumstance was a self-understood fact for many researchers. However, demonstration of this effect is interesting from the general biological point of view. Such a reaction of the human visual system to a photic stimulus confirms the "optimal" adaptation of human vision to the habitat. It is not difficult to imagine what would happen to man if the time of recovery of light sensivity were to increase proportionately to the increase in power of the photic stimulus over the tested range in accordance with a linear law. This fact may have some significance to the design of an operator's work place and development of his work schedule under conditions where there is significant flucutation of brightness and time is short.

A study we conducted [54] revealed that recovery of visual acuity is related to the magnitude of deadapting light and background brightness of the test table. An effort to express this function in a more integrative form led to derivation of a formula, which yields data about recovery time of visual acuity as related to different combinations of brightness of a test object and brightness of deadapting photic stimulus within the tested range. Apparently, it is more convenient to use the formula in practical work than graphs, diagrams, etc. Moreover,

one can use the formula to find the needed values for graphs, diagrams and tables. However, we should mention that, although the time of recovery of visual acuity is determined by the photic stimulus, there are other factors (noise, vestibular stimuli, vibration, etc.) that could also affect light sensitivity. In addition, of course, the blinding light stimulus must be below the level of nociceptive, injurious light, i.e., it must be adequate.

It should be stated that Bridges simulated the process of recovery of light sensitivity of peripheral vision at an earlier time [50]. He derived a formula for recovery of light sensitivity to the initial level after exposure to a brief flash with brightness of $1.23 \cdot 10^6$ to $9.997 \cdot 10^2$ foot/L lasting 0.0912 to 0.0059 s:

$$\log t_a = x \cdot \log L \cdot T + y$$

where t_a is adaptation time; L is brightness of flash; T is duration of flash; x and y are constants that vary in different people.

V. I. Shostak [53] plotted a graph in the form of a three-dimensional figure showing the dynamics of recovery of discriminatory sensititivity with change in brightness and duration of a deadapting flash, as well as brightness of adaptation background.

Both authors simulated recovery of light sensitivity after a brief deadapting flash and therefore obtained data that differed quantitatively very markedly from ours. We found no works in the literature dealing with mathematical modeling of the process of recovery of spatial sensitivity of central vision after prolonged light adaptation.

For additional verification of the derived formula [54], the parameters of a blinding photic stimulus used in [55] were used in it. The time of recovery of central vision sensitivity calculated by this formula, after prolonged deadaptation (10 min), coincided with the data of the investigations. But the time of recovery of central vision after deadaptation by a brief flash calculated with this formula did not coincide with the data obtained by the above-mentioned authors. These results indicate that prolonged and brief photic stimuli have different effects on recovery of central vision. The question itself is of both theoretical and practical interest, but has not been studied enough. Theoretically, it is interesting to define the range of valid patterns, which are apparently related to different visual mechanisms. For practical needs, it is desirable to define dark adaptation following different types of blinding. It must be stressed that a previous study [49] of the deadapting effect of 3N-8 incandescent lamps and solar rays on recovery of sensitivity of central vision failed to demonstrate appreciable differences between these processes, other conditions being equal. Virtually the same blinding effect has been observed from color and white light sources [4, 30-32]. In our opinion, these data can be interpreted as follows. Apparently, the speed of dark adaptation is not so much determined by the spectral component as by the brightness characteristics of both the blinding light source and illumination of the test object. In this situation, special cones that perceive only brightness may be the main light-perceiving receptors of the retina [45, 56, 57]. Otherwise, changes in spectral composition of blinding light (in nature it changes constantly over a wide range) would cause considerable fluctuations in speed of the process of visual adaptation. The biological desirability of a stable adaptation process after exposure to blinding light sources with different spectral characteristics appears unquestionable, from the standpoint of providing for homeostasis of the body over a wide range of living conditions.

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BIOLOGICAL RESEARCH IN SPACE

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[Article by M. G. Tairbekov and G. P. Parfenov, submitted 22 Oct 80]

[English abstract from source] The paper presents the results of investigations carried out during the last two decades on various biological objects--microorganisms, plant seeds, insects, higher and lower plants, fish and amphibians--in real and simulation space flights. The paper discusses the current knowledge of the biological role of gravity and possible mechanisms of adaptation to weightlessness, as well as the suitability of different biological objects for further space studies. Most experiments conducted in real space flights have lent support to the theoretical studies of the level and limits of weightlessness effects upon biological systems. Analysis of the data obtained in space and ground-bound experiments suggests that molecular processes are indifferent to an altered gravity and that energy metabolism plays an important role in adaptation of biological systems to zero-g.

[Text] The development of biology has been characterized by several fundamentally important events. The great discoveries of the 19th century--Darwin's teaching on the origin of species, that of Schleiden and Schwann on universality of structure of the living cell, Mendel's laws of inheritance of traits, the revolutionary essence of which consists of appearance of new biological disciplines: evolutionary biology, cytology and genetics--had enormous importance. This process was continued in the 20th century. While the 12-year period between the discovery in 1953 of the "double helix" structure of DNA by Watson and Crick and the definitive identification of the genetic code in 1965 is generally considered to be the time that molecular biology was born, the inception of space biology as an experimental science can be said to have occurred on 12 April 1961, the date of the historical space flight of Yu. A. Gagarin.

One of the most important and fundamental tasks for space biology is to determine the role of gravity in evolution of the organic realm on earth. At the same time, studies conducted on space vehicles and in ground-based laboratories pursued several scientific and practical goals: to study the effects of space flight factors on different stages of development of organisms; to investigate the distinctions of mechanisms of adaptation of biological systems to space flight factors; to develop and substantiate the principles for creating an ecological system in the limited area of spacecraft.

There is a certain order to development of the above problems, since the solution of some of them is a guarantee that others will advance. For example, it is impossible to define the distinctions of adaptation to weightlessness without thorough analysis of the facts on biological effects of this factor on levels of organization (from cellular to population). A reliable biological substantiation of life support systems can be offered only after elaboration of the ecological-physiological principle for selection of components of the biological system and practical testing of its function.

The successful development of space biology as an expe[illegible]ntal discipline also depends on a number of other factors: choice of object[illegible] [illegible] study, use of new methodological procedures and availability of special [illegible]earch equipment.

Development and operation of space vehicles made it possible to investigate the distinctions of development of organisms in weightlessness. During the first years of exploration of space, most experiments with various biological objects were conducted aboard manned spacecraft and orbital stations. Subsequently, automatic biological satellites of earth were used for this purpose.

The distinction of biological satellites is that their construction, scientific equipment, life support systems, as well as duration of flights and other parameters were governed entirely by the interests of the experiments. The experimental conditions provided for returning the biological objects to earth in order to continue the studies under laboratory conditions. The experimental research conducted in space in the last two decades can be divided into several stages, which differed in formulation of problems and choice of object studied. At the first stage of research the objective was to determine whether organisms can survive for a long time under space flight conditions.

Intensive experiments were conducted with dry seeds of higher plants in order to demonstrate the radiation effects of space flights in the presence of weightlessness. The first experiments with plant seeds were performed aboard the second artificial earth satellite in 1960 [1]. The experiments with Crepis capillaris seeds aboard the Cosmos-368 satellite can be considered the typical research of this type [2]. It was shown that there was no statistically reliable difference in mitotic indexes of plant cells raised on earth from experimental and control seeds. Preirradiation of the seeds in all experimental variants led to an increase in radiation damage, which consisted of a higher incidence of chromosomal aberrations.

A comparison of the results of experiments with higher plant seeds at different levels of gravity revealed that gravity does not essentially alter the magnitude or direction of effects induced by space flight factors. This apparently confirms the hypothesis that not all of the effects can be attributed to weightlessness. Several experiments were conducted with seeds to study the long-term sequelae of space flights [3, 4]. A study was made of rate of development, viability and genetic characters of plants raised from seeds exposed to weightlessness for different periods of time.

The results of the studies revealed that space flight factors do not have an appreciable effect on subsequent development of seedlings. There was only a tendency toward increase in viability of seedlings at the phase of formation of cotyledons and slower rate of plant development. These and many other data [5-7] warrant the

conclusion that weightlessness per se does not have a lethal effect on seeds of higher plants and does not cause any appreciable differences in morphology and physiology of plants in the process of sprouting from seeds that had been flown in space. As for other factors of space flights, the information about their possible effects on dry seeds is so contradictory that we can only concur with the opinion of most researchers, that it is not expedient to use seeds of higher plants as an object of research in space biology. Apparently, the only the exception would be experiments, in which dry seeds serve as biological indicators for analysis of strong interactions between the heavy component of galactic cosmic radiation and a living substance. However, this question remains debatable, because the results cannot be reproduced [8].

Experiments with microorganisms during space flights have been conducted since 1960. The results of these studies have been systematized, with regard to both their scientific and practical importance, and future prospects for using them in flight experiments [9, 10]. The results of these studies warrant the conclusion that the constant space flight factors, in particular weightlessness, do not elicit appreciable changes in processes of spontaneous and induced mutagenesis; they do not influence growth, development and survival of microorganisms, nor do they have a modifying influence on the radiation effect.

Thus, all of the fundamental biological processes occur normally in prokaryotes in weightlessness. This conclusion conforms entirely with the theoretical premises that ensue for the evaluations of Pollard and Kondo [11, 12], who demonstrated that weightlessness cannot have a substantial influence on molecular processes in prokaryotes, since the thermal energy of their subcellular structures, which is expressed in Brownian movement, is greater by about a factor of 10^2 than the potential energy they receive under the influence of earth's gravity. Consequently, microorganisms are gravity-independent. By the end of the 1960's, when the validity of this conclusion was almost obvious, experiments conducted with Neurospora aboard Gemini-11 yielded data that were not entirely consistent with these conclusions. A difference was found in viability, mutability and physiological activity of experimental and control Neurospora [13, 14]. To verify these results experimentally, a genetic experiment was conducted aboard the Cosmos-605 biosatellite with Bacillus subtilis [5], from the results of which one could assess not only viability but effectiveness of processes of genetic repair and recombination. Both these processes provided for stability of DNA in the cell and determined the survival of microorganisms, as well as the rate of their growth. Four strains were used in this experiment, which differed in capacity for genetic recombination and repair of DNA. In postflight studies, the effects of weightlessness on these processes were assessed on the basis of number of viable spores and revertants. Reliable differences between the obtained data and the control could not be demonstrated in any of the variants of the experiment, which lasted about 20 days. Weightlessness did not affect the effectiveness of repair and recombination processes in prokaryotes.

The results of this experiment made it possible to offer a definitive answer to the question of desirability of further use thereof. The microbiological studies conducted in space between the early 1960's and early 1970's had practical importance, since they yielded encouraging forecasts as to the feasibility and safety of space flights from the standpoint of cellular processes. As for the scientific aspects of the research done with plant seeds and prokaryotes, they confirmed the validity of the theoretical hypotheses concerning the gravity-independence of processes

limited to the molecular level and lack of involvement of weightlessness in modification of the radiation effect on an organism with low metabolism. The participants in microbiological studies in space conducted in the United States, in particular with Neurospora aboard Gemini-11 arrived at analogous conclusions [16, 17]. Future studies in this direction must apparently be related to elaboration of technological principles for culturing microorganisms in closed ecological cycles, as well as questions of medical monitoring of the distribution [or spread] of pathogenic forms of microorganisms during space flights.

The second stage of development of space biology was characterized by broader use of materials and methods of investigation. Since the 1970's, experiments have been conducted with insects, fish, amphibian eggs and fish roe, higher and lower plants, as well as small laboratory animals (rats) aboard biological satellites and manned spacecraft. In most experiments conducted at this stage an effort was made to determine whether the mechanisms that implement different biological functions operate normally in weightlessness.

Until research was conducted in space not only with microorganisms and plant seeds, but insects, mainly the drosophila (Drosophila melanogaster). The drosophila (small fruit fly) had already been used during the flights of vertical rockets. Several dozen experiments had been conducted with it on space vehicles. Most of them had the goal of determining the mutagenic effects of space flight factors, primarily weightlessness [18-20]. In most cases, the authors attributed the higher incidence of mutations, if it was present, to the effects of factors that are not specific to space flights (vibration, accelerations, etc.). As a result, it was demonstrated that weightlessness does not have a mutagenic effect, or else that it is a mild mutagen, chiefly with regard to genome mutations.

The next series of experiments was conducted on Cosmos biosatellites, and it had broader tasks: to study the biology of drosophila development in weightlessness. In these studies, special attention was devoted to the rate of insect development, survival rate, life span, anatomy and biochemical processes (specialists from the United States participated in these experiments). The influence of weightlessness on vital functions of two generations of drosophila was studied during the flight of the Cosmos-782 satellite, on which a centrifuge was installed. Postflight studies failed to reveal a difference in rate of development of drosophila kept on a stationary platform during flight (weightlessness), put in the onboard centrifuge (artificial gravity of 1 G) and those studied in a ground-based synchronous experiment [21, 22].

Subsequently, when analyzing the results, the idea occurred of using the onboard centrifuge to study the ecological significance of the gravity factor. This experiment was conducted during the flight of the Cosmos-1129 biosatellite. An onboard instrument was developed, which consisted of a centrifuge in the shape of a cross with four arms, on each of which feeders were installed at distances from the center corresponding in weightlessness to accelerations of 0.3, 0.6 and 1 G.

The significance of gravity as an ecological factor was evaluated on the basis of the gravity preference of drosophila, comparing the density of populations developing in feeders in zones of different magnitudes of accelerations. Moreover, a record was also kept of the amount of defecation in these zones, which made it possible to determine how long adult specimens spent in these zones. Population density was determined from the number of pupae and puparia (scales left from the pupae), i.e., not only already developed specimens were taken into consideration,

but those that began to develop in weightlessness. In a control experiment on earth using an analogous centrifuge, the accelerations in the zones with the feeders constituted 1.1, 1.4 and 1.7 G. Analysis of the obtained data revealed with statisticaly reliability that changes in gravity in the range of 0 to 1.7 G do not affect development and behavior of drosophila. It is important to study the behavior of animal organisms with altered gravity in the practical sense, since it has a bearing on cosmonautics. To date, there is prevalence of the view that the absence of gravity could cause serious changes on all levels of organization of living organisms. The negative geotropism in the drosophila is an example of adaptation created through natural selection. The drosophila's habitat is the boundary between a firm and gas environment. Organisms weighing less than 1 g (which include the drosophila) live, as we know, in the world of surface tensions, and their behavior is determined by the boundary conditions between environments. The influence of these conditions on morphogenesis of small animal organisms is much greater than the possible effects of gravity. It is only for large animals that gravity is the main factor of shape formation.

It is not by change that specialists were interested in beetles as an object of research in space biology. For several decades, various beetle species have been used in experiments, particularly those dealing with radiation and population genetics. Simple and precise methods of genetic analysis have been developed for this object, in particular, for counting dominant lethals according to embryonic and larval deaths. The beetle develops in about 40 days, i.e., a time approximately equal to a flight of average duration. The density of beetle cultures at the embryo stage could amount to 1000/g nutrient medium, which usually yields statistically reliable results when conducting comparative studies. One of the beetle species (Tribolium confusum) was included in the research program of American specialists aboard Biosatellite-II in order to investigate the combined effect of weightlessness and ionizing radiation. Postflight studies failed to demonstrate differences between control and experimental data. Tribolium constaneum beetles were used in an experiment aboard the Cosmos-605 satellite, where embryological problems were worked on. Since this mission lasted only 20 days and this was not enough for the complete cycle of development of this beetle, specimens were put aboard at the stages of embryos, pupae and larvae. As a result of this experiment, it was established that there was normal production of larvae and pupae, pupation and metamorphosis in weightlessness. At all stages of development, the survival rate was about the same as in the control.

A large cycle of studies with the flour beetle was conducted aboard the Salyut-6 orbital station. The time during which this station was functional in space made it possible to study vital functions, morphogenesis and mutability of this beetle in weightlessness over several generations. This was the main distinction of this experiment. In addition, involvement of cosmonauts in the studies assured proper performance of operations to cross specimens and move them to fresh nutrient medium. Postflight studies recorded the number of live and dead insects at all stages of the life cycle. The results of statistical processing of the data revealed that the complete cycle of beetle development, from fertilization to appearance of specimens of the next generation, takes place in weightlessness. The quantitative indicators of the parameters studied were the same in the experiment and control.

Thus, the research done in space with insects demonstrated that the weightlessness factor was not involved in processes that regulate the main parameters of vital functions of living organisms, the mean weight of which is below the critical range.

Specialists started to be concerned with the distinctions of growth and development of higher plants in weightlessness from the time the problem of developing biological life support systems for spacecraft emerged. Raising higher plants aboard space vehicles and conducting studies with them under these conditions involved considerable technical difficulties, since it was required to provide specific conditions with respect to light, temperature, humidity, etc. For this reason, in spite of the fact that the experiments with higher plants were conducted aboard spacecraft in virtually every mission, it has still not been possible to obtain a complete cycle of plant development in weightlessness and have substantial results.

Intact plants, cut inflorescences of Tradescantia, as well as the buds of plants whose pollen was at the premeiotic stage of division, were stowed repeatedly aboard Cosmos-110, Vostok and Voskhod spacecraft [23-27]. Cytogenetic analysis made after the flights revealed that chromosomal and genomal disturbances developed. It was demonstrated that microsporogenesis and macrosporogenesis occurred normally in weightlessness, although up to 2-3% impaired mitoses were demonstrable. Analogous findings were made in Tradescantia by American specialists during the flight aboard Biosatellite II.

The first attempt to grow plants from seeds in weightlessness was made on the Salyut-1 orbital station in the Oasis-1 instrument. Subsequently, pea, wheat and arabidopsis seeds were grown to a certain stage (formation of generative organs) aboard Salyut-4 and Salyut-6 orbital stations. The results of all these experiments revealed that germination of seeds of different species of higher plants occurred without difficulties in weightlessness. There was no change in germinative capacity of seeds, energy of sprouting and rate of plant growth. However, repeated morphological, cytological and cytogenetic analysis of material obtained from these experiments revealed that there were differences between experimental and control plants. In particular, there were differences in size and shape of cells in the tissues of supporting organs. Experiments conducted to determine the orientation of plant organs in weightlessness occupy a special place in the research on higher plant growth in weightlessness.

This was the objective of a series of experiments with sprouting seeds of the higher plants Crepis (Crepis capillaris), pine (Pinus silvestris), tomato (Lycopersicum escul.) and certain others, which were conducted aboard Cosmos-690, Cosmos-782, Cosmos-936, Cosmos-1129 biosatellites and the Salyut-6 orbital station [28, 29]. As a result two factors of basic importance were demonstrated: In the first place, orientation of the vital organs of higher plants is not genetically programmed, and it is governed by endogenous tropisms. In weightlessness, it depends on the original location of seeds in the substrate, and it is determined by the morphology of the embryo. Only seeds that were planted as embryos in the substrate sprout correctly (i.e., as they do on earth) in weightlessness. In all other cases, the seeds produce shoots whose roots and stems have the same direction as the embryonic organs in the seeds. However, in all of the experimental variants, both in weightlessness and the ground-based control, the polarity (i.e., approximately opposite direction of growth of main organs) was unchanged. This shows that the polarity of growth of primary organs is genetically determined and unrelated to exogenous factors. The obtained results offered experimental confirmation of the theoretical hypotheses that a gravity stimulus is needed for correct orientation of plants. In our opinion, there should not be any other basic obstacle to normal development of plants in weightlessness. Apparently, the unsuccessful attempts to raise plants aboard space vehicles are related to technical flaws in onboard greenhouses.

However, while they recognize the causes mentioned above, some authors still believe that the frequently observed loss of plants in weightlessness in the transitional stage between vegetative growth and generative development is attributable to impairment of normal distribution in the cell of growth hormones and other biologically active substances [30]. To verify this hypothesis, an experiment was conducted aboard the Cosmos-1129 satellite with a plant that has a short developmental cycle, Arabidopsis (Arabidopsis taliana). The main objective of this experiment was to observe the generative cycle in plants, in weightlessness, starting with fertilization and ending with maturation of seeds. The plants were stowed aboard in plexiglas cartridges 150 ml in size, in moist soil; during the flight, illumination constituted 8 W/m². The plants completed their life cycle in 18.5 days (duration of this biosatellite's flight). Mature and viable seeds were produced in some inflorescences, and the next generation of plants was grown from them on earth, showing no difference from the control. Thus, evidence was obtained of the possibility of generative phase of plant development in space. In this regard, it is apparently opportune to mention the experiments with isolated somatic carrot seeds conducted by American specialists aboard Cosmos-782 and Cosmos-1129 satellites [31, 32]. As shown by the results of postflight analysis and development of plants raised from embryonic cells exposed to weightlessness, somatic development during space flights lasting 20 and 18.5 days was normal, i.e., it was the same on earth and in weightlessness.

Thus, most of the experiments with living organisms in weightlessness revealed that the mechanisms regulating the main biological processes are essentially not very sensitive or completely insensitive to the absence of gravity. However, in the course of the studies, it was found that, although weightlessness does not have a direct deleterious effect on biological systems, it can nevertheless alter the normal course of processes, for the occurrence of which there must be a gravity stimulus. There is particularly distinct manifestation of the destabilizing effect of weightlessness in those cases where there are no specialized systems (before they are formed) that are designed for purposeful coordination of the operation of different functional units. A typical and vivid example of such processes, when there must be integration and coordination of diverse and barely related morphogenetic movements, is embryogenesis and, first of all, its early stages. We indicated above just how the destabilizing effect of weightlessness is manifested in orientation of seedlings. Typical disturbances caused by absence of gravity or with simulation of the effects of weightlessness on earth (continuous use of clinostat) were also demonstrated in experiments with fish roe and amphibian eggs. In experiments conducted aboard Cosmos-782 involving fertilization of roe of the fish Fundulus heteroclitus, nonspecific depression and desynchronization of different types of cell movement were observed [33]. On this basis, it was concluded that the primary effects of weightlessness on fish could be related to depression of segregation-transport processes. However, these effects can occur only at the very earliest stages of cleavage of fertilized roe before formation of the gastrula. This is confirmed by the results obtained by American specialists in the same experiment aboard Cosmos-782, where they failed to demonstrate an effect of weightlessness on fish development after the gastrula stage [34]. However, the anomalies that are observed, which are caused by weightlessness or simulation of the effects of this factor, usually revert to normal, i.e., they are reversible and do not lead to death of the organism at later stages of development.

The level of our knowledge at the present stage is not determined solely by the results of experiments conducted aboard Salyut and Skylab orbital stations and biological satellites of the Cosmos series. Much of what pertains to basic problems

of the biological role of gravity is also being solved on earth, with simulation of the effects of weightlessness by means of laboratory instruments (clinostats and centrifuges). In the last few years, the functional approach to this problem is growing increasingly significant in such studies.

The results of biomedical research in space indicate that it is possible, in principle, for terrestrial organisms to exist in weightlessness for a long time. However, while man remains in generally satisfactory condition when exposed to weightlessness for a long time, some functional systems present characteristics that differ from normal. We refer, first of all, to the cardiovascular system, where weightlessness immediately eliminates the gradient of hydrostatic pressure, thereby causing redistribution of blood and body fluids. Somewhat later on, there are changes in the skeletomuscular system, which are characterized by appreciable increase in excretion of calcium in bones and atrophy of some muscles.

This facts, which we know from the practice of manned flights, give us cause to ponder on the biological essence of the phenomena that occur. Apparently, the observed deviations mean that the body, as a dynamic system, shifts to a new stationary state. Special preventive measures, which have been developed in space medicine, can, in principle, retard or accelerate this process, normalizing the state of man in weightlessness with respect to some criteria. As for biological objects, the development of events is unequivocally determined by the slow drift of systems toward a new stationary state.

One of the integral parameters of the functional status of the organism is the level of energy processes, which is determined chiefly by the intensity of aerobic oxidation of substrates, synthesis, accumulation and expenditure of ATP, the main energy resource of a biological system.

In studies conducted under laboratory conditions simulating the effects of weightlessness on sprouting seeds of higher plants, a reliable change was demonstrated in energy processes--oxidative phosphorylation and ATPase activity [35, 36]. The results are indicative of the probability that one can expect changes in weightlessness with regard to overall energy metabolism of developing organisms, especially at the early ontogenetic stage. That a different structure corresponds to weightlessness than on earth is indicated by the results of biological experiments conducted with different objects. Wtih regard to mammals, this applies primarily to the skeletomuscular system (osteoporosis, morphofunctional changes in the muscular system). As for plants, weightlessness is apparently the cause of disorientation of the main organs, some types of morphosis (spiralization of stems and roots, change in shape and size of cells). Evidently, performance of a number of functions in weightlessness may involve different expenditure of energy, occasionally greater, but more often lesser, than on the ground. The first experimental confirmation of this hypothesis could be the results of an experiment with the lower fungus, Physarum policephalum, aboard Cosmos-1129, where a noticeable decrease in rate of the growth process was demonstrated, the intensity of which is a good indicator of energy metabolism in cells.

In the next experiments in space, apparently this hypothesis will have to be verified, and studies will have to be made of the dynamics of heat production by the organism as an indicator of its adaptation to prolonged existence in weightlessness. One of the objectives of such research will be to determine the dynamics of transition of an organism to a stable state. Of greatest interest, with this formulation of the problem, are the early stages of ontogenesis, as well as

stages related to transitory processes. It is expressly at these stages of development of the organism that the effects of weightlessness might be the most noticeable.

Thus, as a result of 20 years of research in the field of space biology and analysis of findings from experiments with biological objects aboard space vehicles, one can formulate several conclusions of basic importance and outline the route of future development of studies in weightlessness and ground-based laboratory conditions with simulation of the effects of this factor.

It can be considered established that weightlessness does not affect molecular processes occurring in the cell at the genome level, which implement translation, transcription and repair of genetic material. Weightlessness does not increase significantly the incidence of mutations. Consequently, of the "three whales" [7] upon which rests the evolutionary process, only natural selection remains unstudied. In the next 10 years, specialists in genetics dealing with space biology should concentrate, apparently, on defining the direction and intensity of natural selection.

Numerous flight experiments on various biological objects (higher and lower plants, fish, amphibians and mammals) revealed that weightlessness, as one of the environmental factors, may cause deviations from normal functional status of an organism, and these changes are more marked at the early stages of development.

However, such deviations are adaptive in nature, they are regulated in the course of subsequent development, and they do not lead to death. Energy processes play an important role in regulating these disturbances. Evidently, the study of the distinctions of energy metabolism in organisms is one of the real routes for gaining understanding of the mechanism of adaptation to weightlessness and evolutionary role of gravity.

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ANIMAL EXPERIMENTS ABOARD BIOSATELLITES OF THE COSMOS SERIES (RESULTS AND PROSPECTS)

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 2, Mar-Apr 81 pp 60-66

[Article by O. G. Gazenko, Ye. A. Il'in, V. S. Oganov and L. V. Serova, submitted 30 Oct 80]

[English abstract from source] Results of animal (rat) experiments carried out onboard biosatellites Cosmos-605, 690, 782, 936 and 1129 are presented with emphasis on changes in metabolism and musculo-skeletal system. The modifying effect of weightlessness on the animal radiosensitivity is considered. The use of artificial gravity as a countermeasure against adverse effects of weightlessness is discussed. As an immediate perspective, primate experiments aimed at a detailed study of the mechanisms of weightlessness induced changes in the structure and function of the cardiovascular, musculo-skeletal and vestibular systems are described.

[Text] The world's first manned flight into space was preceded by numerous experiments on animals in flights on rockets and artificial satellites of earth. In these experiments, a study was made of endurance of factors related to launching, brief weightlessness, descent and landing of flight vehicles.

The years directly preceding man's first flight into space were a period of the most intensive development of research in the field of space biology in our country. This was aided, in particular, by the development of returnable space satellites (SS). Organisms on the most diverse levels of evolution of life were used as experimental objects during flights in these satellites, ranging from viruses to mammals (dogs and others), which made it possible to assess the effect of factors involved in a short (1 day) space flight, mainly weightlessness, not only on the integral organism, but on the tissular, cellular and molecular levels. Much attention was devoted in these experiments to genetic studies of the effects of space flight factors on genetic structures of somatic and embryonic cells of different organisms.

Analysis of the results obtained by Soviet scientists who examined biological objects that had been flown aboard satellites revealed that it is possible for man to safely fly in space. At the same time, the experiments aboard SS and then on the Cosmos-110 biosatellite established that space flight factors are not indifferent to many biological systems. Development of specialized biological

satellites of the Cosmos series constituted a basically new stage in the development of space biology.

Since 1973, 5 biosatellites have been launched in the Soviet Union: Cosmos-605 (1973), Cosmos-690 (1974), Cosmos-782 (1975), Cosmos-936 (1977) and Cosmos-1129 (1979). The duration of the flights of these biosatellites ranged from 18.5 to 22 days, and no preventive methods whatsoever were used against the adverse effects of weightlessness.

The main objectives of the research pursued during the biosatellite missions were to study the mechanisms of effects of weightlessness on structural and functional parameters of physiological systems of the organism, experimental evaluation of the possibility of using artificial gravity (AG) to normalize the functional state of the organism during space flights, and studies of the modifying effect of weightlessness on radiosensitivity of mammals.

Animals and plants of the most diverse taxonomic ranks, from unicellular organisms to such mammals as white laboratory rats, which became the traditional object of research in the field of space biology and medicine, were used to solve the above problems as experimental objects of studies aboard biosatellites.

Since it was assumed that experiments aboard the Cosmos biosatellites (these distinctive biological laboratories) would become one of the major directions of work in the field of space biology, it was necessary, first of all, to elaborate a program of scientific experiments [1], as well as general methodology of preparing and performing them [2].

As a result of numerous ground-based experiments, systems and methods were worked out for variuos forms of experiments aboard biosatellites; biometric and physiological-hygienic animal characteristics were defined, methods were developed for screening and training animals for space flights, as well as optimum feeding of animals in flight; the principles for designing a life support system for animals and for methods of biotelemetric monitoring of their condition in flight were substantiated; recommendations were prepared for equipment for totally automated long-term experiments on mammals aboard the Cosmos biosatellites.

One of the basic distinctions of the research program for Cosmos biosatellites was that so-called synchronous control experiments were conducted on the ground. In these experiments, which were conducted in biosatellite mock-ups, all of the physiologically significant space flight factors were simulated, with the exception of weightlessness, which permitted comprehensive comparative analysis of the animals' condition in space flight and on the ground, as well as to derive founded conclusions as to the effects of weightlessness and other space flight factors on vital functions.

Another distinction of the program was that the first phase of postflight physiological, morphological and biochemical studies was conducted directly in the area where the biosatellite equipment was landed, in specially designed field laboratories equipped with an air-conditioning system, so that the planned studies could be conducted in virtually any weather. Such an approach to postflight studies made it possible to start working with the biological material as early as 3-5 h after the biosatellite landed, which was important to differentiate between changes due to weightlessness and those related to the influence of factors of descending from orbit, landing and then readjusting to earth's gravity.

The main result, of practical importance, of the studies was determination of the fact that weightlessness did not elicit irreversible pathological changes in any organ of the experimental animals. Nor did it affect the life span of the animals. At the same time, after the flight, many reversible changes were found in many organs and systems. In some cases they were very minor, and in others significant. These changes were arbitrarily divided into two groups: specific, which were related to the effect of weightlessness, and nonspecific, which were related to development of a stress reaction at various stages of the flight. Of course, such a division is very arbitrary, since so-called specific changes can develop not only in weightlessness, but in the presence of a number of similar factors (for example, hypokinesia, hypodynamia and others). Be that as it may, this division was convenient for analysis of the data.

The aggregate of data obtained from morphological, biochemical and physiological studies conducted in the experiments aboard biosatellites forms a rather clear picture. It shows that the severity of changes demonstrated in various structures (muscles, skeletal bones) and elements of the skeletomuscular system was consistently related to the degree of their involvement in antigravity activity in a given animal species, and in the case of various slow (antigravity) muscles, it was also related to their anatomical-topographic and biomechanical distinctions.

Analysis of morphological [3-5], biochemical [6-9], cytochemical [10] and physiological [11, 12] studies conducted during experiments aboard biosatellites revealed that the changes occurring in skeletal muscles under the influence of space flight factors not only were indicative of development of functional atrophy in some of them, but of distinct adaptation.

In particular, it was shown that changes in contractile properties specific to slow and fast muscles are associated with adequate alteration, in each instance, of molecular composition of contractile and regulatory muscular proteins.

On the whole, considering the complete reversibility of the described changes, the findings confirm the known data concerning lability of phenotypes of muscle fibers [13, 14], and they may be indicative of high functional flexibility of skeletal muscles when functional requirements change (in this instance, magnitude of the gravity field). The latter should be interpreted as a p ›gnostically favorable sign, from the standpoint of feasibility of controlling man's adaptation to space flight conditions.

The changes occurring in bone tissue are also reversible, but they present great inertia in their involution during the readaptation period. It may be assumed that the slower growth of skeletal bones and slower processes of mineralization thereof [15-18], diminished strength characteristics of skeletal bones [19], as well as increased sensitivity to loads on the spinal column [20] observed in the experiments are attributable, among other causes, to general change in Ca balance in animals during flights [21]. The results of experiments on animals revealed that the closest attention should be given to this problem.

The nonspecific changes include signs of a moderate stress reaction, which were demonstrated after the flight in the hypothalamo-hypophyseo-adrenal system, lymphoid organs, blood, gastrointestinal tract and myocardium [4, 22].

Some manifestations of the stress reaction had been repeatedly observed by cosmonauts during missions varying in duration; however, it is only the animal experiments that provided quite completely the topography of changes occurring in different elements of functional systems involved in nonspecific adaptation reactions.

It is expedient to consider the correlation between specific and nonspecific effects of space flights on the example of metabolic changes since, as shown by the obtained data, space flights are associated with changes in virtually all forms of metabolism.

Nucleic acid metabolism is changed. In particular, the decrease in RNA content of Purkinje cells, cerebellum, large neurons of intervertebral ganglia of the spinal cord, liver and spleen is a manifestation of these changes. The overall direction of changes conforms with the well-known hypothesis of F. Z. Meyerson [23], according to which hyperfunction of an organ is associated with activation of synthesis of nucleic acids and proteins, while diminished activity leads to depression of synthesis [22].

There were great changes in lipid metabolism, and there are data indicative of activation of lipolytic and lipogenetic processes [24]. We were impressed by data concerning a decrease in phospholipid content of the microsomal fraction of muscles [25], which suggests that there may be changes in membrane properties in weightlessness.

Such data as the change in spectrum of LDH isozymes in skeletal muscles, change in levels of blood glucose, lactate and pyruvate, changes in activity of enzymes of carbohydrate metabolism in the liver and others are indicative of changes in carbohydrate metabolism [22].

The changes in fluid-electrolyte metabolism were manifested by loss of fluid and electrolytes. Postflight examination of animals revealed an inadequate reaction to the K load test, which was manifested by the fact that, in spite of the K deficiency in the organism, there was diminished capacity to retain it [26].

It was also significant that, during flights lasting one-fiftieth of the animals' life, there were signs of activation, as well as catabolic and anabolic processes. For example, activation of proteolytic enzyme systems in all parts of the gastrointestinal tract, retardation of growth of animals, reduced mass of muscles, etc., were indicative of activation of catabolism; such findings as increased assimilation of feed by animals during the flights, a tendency toward increased O_2 uptake and a few others were indicative of activation of anabolism. Evidently, with flights lasting this long, the organism is capable of partially compensating for dissociation processes that occur as a reaction to inadequate activity of the skeletomuscular system.

The nonspecific and specific changes due to prolonged weightlessness, which were demonstrated in the animal experiments aboard the Cosmos biosatellites, are indicative of the need for a continued search for ways and means of maintaining an optimum functional state of the organism during long-term space flights. It must be borne in mind that the preventive measures (physical exercise, lower body negative pressure, pharmacological agents) currently used in manned space flights do not eliminate entirely the adverse changes in cosmonauts. Moreover, the use of

these preventive measures usually requires much time, which reduces the time for cosmonauts to rest and work usefully.

In this regard, we consider quite important an experiment conducted for the first time in space on rats that were submitted to artificial gravity of 1 G throughout the flight. Inclusion of such an experiment in the flight program of Cosmos-936 made it necessary to develop the methodology for conducting it and creating a special onboard centrifuge equipped with all that was needed as life support for the animals and to monitor their condition during a flight lasting 18.5 days.

An equally important objective of the experiment with artificial gravity was to create aboard the biosatellite an ideal control group of animals that would be submitted to all of the space flight factors, with the exception of weightlessness. The presence of such a group of animals, along with animals submitted to weightlessness, should have made it possible to make a better distinction between the physiological effects of weightlessness and the influence of other space factors.

In conducting the experiment with rats aboard the Cosmos-936 biosatellite, attention was focused mainly on studying the physiological effects of artificial gravity as one of the possible means of maintaining an optimum functional state of the organism during long-term space flights.

The results of these studies revealed that artificial gravity prevented onset during space flights of such adverse changes as decrease in ATPase activity of myocardial myosin, impairment of ion regulating function of the kidneys, deterioration of contractile properties and impairment of metabolism of skeletal muscles, diminished mechanical strength of long bones, hypoplasia of lymphoid organs, retarded weight gain in the postflight period, etc. [22].

Concurrently, it was found that keeping animals in rotating systems for a long time was associated with onset in space flight of such changes as more significant decline of efficiency of higher branches of the central nervous system than in weightlessness, depression of brain metabolism, especially in those regions whose function is related to implementation of motor activity of animals, as well as decreased sensitivity and reactivity of the semicircular canal systems.

These undesirable effects of artificial gravity were most likely attributable to the use, in the experiment aboard the Cosmos-936 biosatellite, of a centrifuge with relatively short arm, which led to appearance of precession and Coriolis angular accelerations. However, this by no means mi mizes the value of the first data obtained on mammals indicating that it is possible, in principle, to use artificial gravity during long-term space flights. Of course, the parameters of artificial gravity for manned space flights will be determined through studies with the participation of man.

We know that one of the important conditions for correct evaluation of the radiation hazard of long-term space flights is knowledge about the modifying influence of space flight conditions on the biological effectiveness of radiation. Unfortunately, no theory has yet been expounded on the combined effect of radiation and nonradiation physical factors of the environment, although efforts have been made to summarize the accumulated data [27, 28].

Among the conditions that could alter cosmonauts' radiosensitivity, one usually singles out factors inherent in powered and free flight. During powered flight, one should mention among the biologically significant factors accelerations,

vibrations and noise. Since their effect is brief, the main factor that could affect radioresistance during long-term space flights should be considered dynamic weightlessness, which occurs in free-flight. The modifying effect of weightlessness on radiosensitivity of mammals was not studied prior to the flight of Cosmos-690. In the USSR and United States, during missions aboard the biosatellites Cosmos-110, Cosmos-368 and Bios-2 and manned spacecraft, efforts were made assess the combined effect of radiation and weightlessness, using biological objects such as insects, unicellular organisms, human tissue cultures and plant seeds. However, because exposure to weightlessness was brief and the difficulties involved in extrapolation from lower organisms to higher ones, it was not possible to make use of these data in practical space radiobiology.

In order to obtain the necessary information about the effect of weightlessness on radiosensitivity of mammals, it was recessary to conduct an experiment under actual space flight conditions with strictly graded irradiation of animals. Such an experiment was performed on rats during the flight of Cosmos-690.

In accordance with the objectives of the experiment, a method was developed to conduct it, including choice of radiation doses and source, refinement of irradiation conditions, development of an onboard radiation emitter with due consideration of the existing standards for radiation safety and specifications for space equipment, development of a uniform radiation field for animals aboard the biosatellite.

In the experiment aboard Cosmos-690, the animals were exposed to radiation from an onboard source on the 10th day of the flight, so that development of radiation sickness and the early stages of the recovery period occurred in weightlessness. The latter circumstance is extremely important, if we consider that the results of this experiment had to be used to assess the radiation hazard of long-term manned space flights.

The results of this experiment warrant the statement that the modifying effect of weightlessness lasting 20.5 days on radiosensitvity of mammals is not considerable. According to various parameters referable, for example, to blood and other critical tissues of the organism, the coefficient of modifying effect did not exceed 1.2 and was mainly close to 1.0.

In other words, the modifying effect of weightlessness on radiosensitivity of rats was found to be within the range of normal fluctuations of radiosensitivity in this animal species. Determination of this fact in an actual space flight was a step forward in assessing the radiation hazard of space flights, as compared to prior studies with simulation of powered segments of space flights under laboratory conditions.

Thus, the experiments with rats aboard Cosmos biosatellites concluded a significant phase of the program of biological research during space flights. The results obtained in the course of these experiments made it possible to evaluate the deleterious effect of weightlessness and ionizing radiation, as well as to disclose several new patterns of adaptation of physiological systems of the organism to space flight conditions and to test promising means of preventing the adverse effects of weightlessness.

At the same time, it must be noted that the facts accumulated to date, which made it possible to establish the phenomenology of effects of weightlessness on living

organisms are not yet sufficient for strictly scientific substantiation of recommendations on biomedical support of manned space flights differing in duration, or for development of measures directed toward preventing or completely eliminating the adverse effects of long-term weightlessness.

The obtained experimental data very obviously show that development of any preventive measures against the deleterious effects of weightlessness is impossible without in-depth studies of the mechanisms of occurrence of structural and functional changes in the most vulnerable physiological systems of man. These systems include, first of all, the cardiovascular, vestibular analyzer and skeletomuscular system.

In spite of the numerous studies conducted during manned space flights, the pathogenesis of changes in hemodynamics and myocardial function in weightlessness is still, unfortunately, not quite clear. It is also deemed important to investigate the correlation between changes in the cardiovascular system and changes in fluid-electrolyte metabolism and metabolism as a whole. In addition, it is still a pressing matter to study the mechanism of development of functional muscular atrophy and osteoporosis, as well as motion sickness in weightlessness.

To solve these problems, there must be continued broad studies with the use of invasive methods, that open the way toward direct recording of blood pressure and blood flow in vessels, studies of neuronal activity of different afferent and efferent systems, etc.

Of course, these problems can be solved the most effectively on experimental animals whose organization is closest to man and for whom the most refined and informative physiological and neurophysiological methods have already been developed. This is why, among other experimental objects, it is planned to use representatives of primates, monkeys, in future studies aboard biosatellites.

Ultimately, the choice of objects to be studied on biosatellites will be determined, we believe, by the specific objectives of the studies and methods of reaching them.

Research aboard biosatellites of the Cosmos series are of considerable theoretical interest as the basis for continued development of gravity physiology. The facts obtained from the experiments could also have much practical importance, and in this regard they will apparently be the subject of in-depth analysis by specialists working in different branches of space biology and medicine.

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MORPHOLOGICAL EFFECTS OF WEIGHTLESSNESS AND PATHOGENESIS THEREOF

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[Article by A. S. Kaplanskiy and Ye. A. Savina, submitted 30 Oct 80]

[English abstract from source] The paper summarizes the results of morphological and histochemical investigations of rats flown onboard the Soviet biological satellite of the Cosmos series. The changes in different functional systems and organs have been found to be related. The paper contains hypotheses concerning the pathogenesis of the changes detected. It is emphasized that most changes are induced by a reduction of load upon the musculoskeletal system in weightlessness.

[Text] The launching of artificial biological satellites of earth of the Cosmos series in the Soviet Union, with rats on board, laid the foundation for systematic morphological studies of the effects of weightlessness on mammals. These studies were conducted within the framework of a vast scientific program, the purpose of which was to work out the theoretical bases and principles of biomedical support of manned space flights. To date, considerable factual material was obtained, and analysis thereof gives us an idea about both the nature of changes occurring in weightlessness and correlation between them.

In this report, we have made an attempt to single out the changes attributable to weightlessness from the aggregate of morphological changes observed in animals after completion of a space flight, as well as to voice some views concerning the pathogenesis of some phenomena.

The results of morphological and histochemical stud[ies] revealed that weightlessness does not elicit specific changes, in the strict sen[se] of the word [specific], previously unknown in earth-based pathology, and that exposure to weightlessness for up to 22 days is not associated with development of severe or irreversible structural changes, although it is not indifferent to animals. In the set of changes that arise under the influence of weightlessness, a large share is referable to processes of functional and structural reorganization of the skeletomuscular system. These changes are not only important per se, but they play a certain role in the genesis of a number of other changes that also develop. The absence of static load and drastic reduction of dynamic load on the skeletomuscular system in weightlessness inevitably lead to hypofunction of this system and, as [a con]sequence, to development of a set of changes inherent in functional atrophy

To sum up the results of bone tissue studies in rats flown aboard biosatellites, it can be stated that weightlessness elicits the following phenomena: inhibition of periosteal new bone formation and growth of long bones in length; development of osteoporosis of spongy and, to a lesser extent, compact substance of long bones; demineralization of osteal tissue and redistribution of minerals in a bone [1-7]. The severity of changes varies in differnt bones, but on the whole it is at a maximum in long bones that have a support function, the metaphyses and epiphyses of the bones being damaged the most and the diaphyses the least [2]. Development of osteoporosis and decrease in compactness and mineralization of bones leads, of course, to decrease in their strength [5, 8], as a result of which some animals presented fractures at the time the biosatellites landed, under the influence of impact accelerations, and these fractures were usually localized in the region of the metaphyses, where maximum porosity of bone tissue was observed.*

One can apparently also relate to demineralization of bones and intensive elimination of calcium from the organism the significant increase in protein-calcium casts in the renal tubules of the SPF colony of rats flown aboard the biosatellites Cosmos-782, Cosmos-936 and Cosmos-1129 [11].**

At the present time, we are not quite clear about the pathogenetic mechanisms, upon which the above-mentioned bone changes are based. It may be that the absence of a mechanical load on bones [16, 17], which it is believed [18] is needed for appearance of an electric potential to stimulate de novo production of bone tissue, plays an important role in development of these changes. The question of whether the electric potential affects bone tissue directly, or whether its effect is mediated by the neuroendocrine system and metabolic processes that regulate bone growth and mineral metabolism remains open. Be that as it may, the data available to us indicate that hormonal regulation of growth and metabolism of bones is altered in weightlessness. This is also indicated by the following facts: diminished functional activity of somatotrophs and concentration of somatotropic hormone in blood [19] of rats in weightlessness; decreased number and functional activity of C cells of the thyroid gland, which produce calcitonin [20, 21]; presence of areas with activated parathyrocytes [21] in the parathyroid glands of rats flown aboard biosatellites, which does not rule out the possibility of some increase in production of parathyroid hormone which is instrumental in releasing calcium from bones. The results of an experiment that demonstrated that osteoporosis does not develop in monkeys with resected parathyroid glands during long-term hypokinesia are indicative of the important role of parathyroid hormone in the process of bone demineralization [22].

Thus, in weightlessness, the systems that are called upon to maintain homeostasis of bone tissue apparently alter their function in such a way as to have the bone structure conform with the diminished load on bones, and the changes that develop in bones (which are pathological from the standpoint of ground-based conceptions) are in essence a normal physiological reaction to the absence of gravity.

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*Decrease in bone density after space flights has also been demonstrated in monkeys [9] and dogs [10].

**An increase in excretion of calcium in urine and feces was repeatedly demonstrated during space flights in man [12-15] and dogs [10].

The diminished functional load on the skeletomuscular system induces, along with changes in bones, development of atrophic processes in muscles, as indicated by the reduction of their mass and cross section of muscle fibers [23, 24]. The muscles of rat hind limbs are more affected than the front ones; of the muscles of the hind legs, the greatest changes are found in the crural muscles, particularly the soleus, which has the main antigravity function [23].

In addition to atrophic changes in the muscles of rats submitted to weightlessness, certain metabolic changes were also noted. However, analysis of these changes must be made with great caution, since the demonstrated changes may be not so much the consequence of weightlessness as a reaction to earth's gravity and the stress it induces (the animals were sacrificed 4.5-9 h after the flight was terminated, i.e., after a period that was sufficient for development of a stress reaction). Nevertheless, some information can be obtained about the metabolic distinctions of muscles in weightlessness.

As shown by the results of histochemical and electron microscopic studies, there was accumulation of glycogen and lipids in rat skeletal muscles after termination of space flights [23, 25, 26], which is probably related to diminished expenditure of energy as a result of reduced functional loads on muscles. Evidently, this was associated with impairment of balance between synthesis and utilization of energy substrates: while the use of glycogen and lipids is drastically reduced, synthesis thereof is inhibited to a lesser extent. On the whole, the impression is gained that, with animals remaining in weightlessness for 18.5-22 days, the process of change of muscular metabolism to a new (lower) level is not completed and this, in turn, is indicative of an incomplete process of rat adaptation to weightlessness. Accumulation of glycogen in muscles of rats submitted to weightlessness, in our opinion, speaks against intensification of glycolytic processes [27, 28], while the shift of the isozyme spectrum of lactate dehydrogenase from the normal "cardia" to "intermediate" apparently occurs after completion of the space flight, as a result of tissular hypoxia that develops due to inconsistency between the increased load on the muscles and inadequate supply of blood to them. There was a decrease in delivery of blood to muscles of rats submitted to weightlessness, as indicated by the results of a quantitative study of the capillary bed of the gastrocnemius, according to which the number of functional capillaries was reduced by almost 30% [29], even 4.5-9 h after returning to earth.

In all likelihood, elimination of a significant number of capillaries from the circulatory system occurs already at the first stages of the space flight, and it is related to diminished functional loads on muscles and decrease in their oxygen requirement. If we consider that this is not associated with a change in circulating blood volume, the emptying of some capillaries should be associated with elevation of blood pressure in large vessels, especially veins, as well as increase in venous return which, in turn, leads to the Henry-Gauer reflex, intensified elimination of fluid from the organism, reduction of circulating blood plasma volume with concurrent thickening and increased viscosity thereof. Normalization of correlations between formed blood elements and plasma occurs as a result of decreased life span of erythrocytes [30], intensified hemolysis thereof [31] and inhibition of erythroid hemopoiesis [32-34]. Evidently, one can also interpret the appearance in bone marrow of rats submitted to weightlessness of a large number of abnormal megakaryocytes [35] as a distinctive defense reaction of the organism to clotting of blood. Indeed, impairment of normal development of megakaryocytes, which are the precursors of thrombocytes, should lead to a decrease in number of the latter in blood, which diminishes the probability of vascular thrombosis with increase in blood viscosity.

The shortage of muscular activity in weightlessness leads not only to atrophy of skeletal muscles, but development of metabolic and structural changes in the elements of the nervous system that are related to muscular function. Thus, there was a decrease in protein and RNA content of motoneurons of the lumbar spinal cord enlargement and sensory neurons of spinal ganglia of rats submitted to weightlessness [36-38], while coarsening of terminals of motor axons was observed in the motor nerve endings [39], as well as decrease in number of synaptic vesicles and mitochondria [40]. These changes in the nervous system very probably arise as a result of diminished flow of afferent and efferent impulsation which, in turn, is caused by the drastic reduction of functional load on muscles in weightlessness.

The absence in weightlessness of the physical loads that rats experienced on earth and the reduction in mass of circulating blood could lead to deconditioning of the myocardium, similarly to what occurred in cosmonauts who participated in long-term space missions [41]. Because of the limited and contradictory data at our disposal, still open is the question of whether myocardial deconditioning is purely functional or whether it is based on structural disturbances. Thus, although histological analysis of the myocardium of rats flown aboard biosatellites failed to demonstrate any appreciable disturbances [42], electron microscopic findings do not rule out the presence of some damage to myocardiocyte mitochondria [43], while biochemical studies are indicative of diminished activity of myosin ATPase and decrease in myocardial sarcoplasmic proteins [44]. The decrease in actomyosin content of the myocardium of rats submitted to weightlessness could logically be attributed to partial atrophy of the myofibrillar system; however, electron microscopy failed to demonstrate lysis of myocardiocyte myofibrils [43].

It was extremely difficult to make a differential diagnosis of changes arising in flight in systems that are involved in the organism's general adaptation reactions in view of development of an acute stress reaction in the early postflight hours. For this reason, one can judge the effect of weightlessness only retrospectively, on the basis of evaluation of reactions to gravity stress and of some more stable criteria. Thus, the dynamics of morphological manifestations of the reaction of the hypothalamohypophyseal neurosecretory system during the first few postflight hours warrant the belief that its function was not increased during the flight. A considerable decrease in number of Herring bodies in the posterior pituitary and reliable decrease in pituicyte nuclei are indicative of the possible decline of initial (base) level of neuronal secretion in weightlessness [45].

After 18.5-22 days in weightlessness, no morphological signs of persistent impairment of adenohypophyseal function on the cellular level were demonstrable. This conclusion was made because of the absence of pathological forms of cells, which appear when there is prolonged impairment of hormone-producing processes, as well as the results of analysis of the condition of endocrine glands whose functions are controlled by adenohypophyseal hormones. The results of biochemical studies, which failed to reveal changes in hormone levels in tissues of the adenohypophysis [19], are also indicative of the absence of substantial structural changes. However, in assessing the state of the adenohypophysis, some signs were demonstrated that were a direct or indirect indication of possible decrease in functional activity of some of its cellular elements, in particular, somatotrophs (reliable reduction of volume of nuclei and cells) and thyrotrophs in weightlessness. The presence of morphological signs of thyroid hypofunction [20, 21] was also indicative of decreased functional activity of the thyrotrophs. Judging by the state of

the gonadotrophs and testes [46], gonadotropic function of the adenohypophysis was not impaired under the influence of weightlessness.

The greatest difficulties were encountered in evaluating the state of adrenocorticotropic function of the adenohypophysis and adrenal cortex in weightlessness, since even at the very earliest times that the animals were dissected (4.5 h after the biosatellite landed) morphological signs of an acute stress reaction had developed in the hypophysis and adrenal cortex [47]. Nevertheless, the consistently observed reduction in mass of lymphoid organs was indicative of increased functional activity of the adrenal cortex during the flight and, consequently, of the presence of a stress reaction in weightlessness. At the present time, it is unquestionable that involution of the thymus and hypoplasia of lymphoid tissue of the spleen and lymph nodes occur during the flight and are attributable to the stressor effect of weightlessness [32, 48].

While hypoplasia of lymphoid organs persisted throughout the flight, the general structure of the adrenal cortex was significantly restored by the end of the flight. Normalization of cortical structure (architectonics of its different regions) by the end of the flight was one of the signs of adaptation of animals to flight conditions, and it warrants the belief that, although weightlessness does have a stressor effect, this effect is not strong. The latter thesis is also confirmed by the fact that even if adaptation to weightlessness was associated with an increase in mass of the adrenals, the increase did not exceed 20%, or else did not reach reliable values.

In spite of the fact that weightlessness elicited development of moderate stress, the very fact that it occurred indicates that there were serious functional and metabolic changes in the animals. It should be stressed that, unlike traditional situations where stress arises in response to an excessively strong factor and is associated with tension of functional systems of the organism and mobilization of all its resources, when changing from earth's gravity to weightlessness the development of stress occurs against a background of drastic reduction of loads on most vital systems.

In addition, we cannot fail to mention that the period of adaptation to weightlessness may be associated with development of emotional stress due to the uniqueness of the situation in which the animal finds itself.

Adaptation to weightlessness and its deconditioning effect on the organism as a whole lead to decrease in resistance to gravity factors, which causes development of acute stress in rats within several hours after returning to earth. Morphological signs of this stress have been repeatedly reported by different authors [32, 33, 48-51], so that there is no need to dwell on them here in detail. The severity of the stress reaction most likely depends on how long the animals are exposed to weightlessness and degree of adaptation to it: the more complete the adaptation to absence of gravity, the more difficult it is to readjust to earth's gravity and the more severe is the stress.

In addition to acute stress, the early stage of readaptation of rats to earth's gravity is characterized by a number of other changes that go beyond the set of symptoms that are specific to stress. These changes include dystrophic lesions to skeletal muscles, in the genesis of which a decisive role is apparently played by tissular hypoxia, which arises as a result of both decrease in number of functional

capillaries and stasis of blood in veins, impaired permeability of venous walls and development of pervascular and interstitial edema in muscles [39]. These vascular changes are apparently due to diminished tonus of the vascular wall as a result of impaired function of the sympathetic nervous system. The validity of this hypothesis is confirmed by the results of observations, which revealed that there is significant decrease in secretion of norepinephrine, which is necessary to maintain vascular tonus, in people submitted to long-term hypokinesia [52].

To sum up all the foregoing, it may be assumed that the absence of loads on the skeletomuscular system in weightlessness not only leads to development of atrophic changes in animal bones and muscles, but is one of the main etiological factors that are the basis of the complex pathogenetic process that determines the entire aggregate of changes occurring in the organism under the influence of weightlessness. Some of the changes observed in weightlessness (for example, in the neuroendocrine system) probably develop in the nature of feedback; others (for example, in the hemopoietic, nervous systems and circulation) are secondary, and they appear because of the decreased physical load on the skeletomuscular system. On the whole, the absolute majority of structural and metabolic changes inherent in weightlessness is definitely related to the decrease in functional loads on the main systems of the organism, while the severity of these changes indicates the level of reduction of functional load on an organ.

Evidently, development of the "general adaptation syndrome" in weightlessness is attributable to the substantial functional and metabolic changes that occur inevitably in animals when they change from earth's gravity to weightlessness, similarly to development of acute "gravity" stress associated with the change from weightlessness to earth's gravity.

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SOVIET RESEARCH ON ARTIFICIAL GRAVITY

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[Article* by A. R. Kotovskaya, R. R. Galle and A. A. Shipov, submitted 30 Oct 80]

[English abstract from source] The paper reviews biomedical investigations concerning artificial gravity performed so far in the USSR. It is believed that at the present stage the major task is to identify the minimum value of artificial gravity which may eliminate adverse effects of weightlessness on the human body. In ground-based investigations high priority should be given to the development of methods of increasing human tolerance to a rotating environment.

[Text] Studies dealing with development of the means of preserving a high degree of fitness of cosmonauts, both in flight and after returning to earth, were begun in the Soviet Union almost simultaneously with preparations for man's first flight into space, at the threshold of long-term orbital flights. Studies pertaining to development of artificial gravity (AG) occupy a special place among the methods of preventing the possible adverse effects of long-term weightlessness on man. Creation of AG aboard a spacecraft would eliminate the weightlessness factor and, consequently, all sorts of adverse consequences of its effects on the body.

As far back as 1911, the great Russian scientist, K. E. Tsiolkovskiy, in his work entitled "Exploration of Cosmic Space by Means of Reaction Devices," wrote: "Even if it were found that man cannot live without gravity, it would be easy to create it artificially in an environment where there is none. For this, man's habitat, be it even a rocket, should have a rotating movement; then, as a result of centrifugal force, seeming gravity of the desired magnitude is formed, depending on the size of the habitat and rate of its rotation.... This gravity is convenient in that it can be as low or high as desired, it can always be eliminated and re-created" [1].

AG, which is created by rotation of a spacecraft, could be in the future a universal means of preventing the adverse effects of long-term weightlessness on man.

*Studies dealing with biomedical issues are discussed here.

A cosmonaut in a rotating space system with AG would be exposed not only to centripetal accelerations that create AG, but to so-called additional linear (Coriolis) and angular (precession) accelerations [2].

The effect on the body of these accelerations may render coordination difficult upon walking, performing a number of work operations, and it could lead to the seasickness syndrome, as well as some optical illusions related to the function of the vestibular system in a rotating system [3-5].

From the biomedical point of view, to settle the AG question, it is imperative, first of all, to determine the minimum level of accelerations that should be used in spacecraft with AG in order to create sufficiently effective artificial gravity for the body and, in addition, to determine the rate of rotation of a system with AG that would be compatible with human life and performance.

The first work dealing with experimental physiological substantiation of minimal AG was done in 1961 under the guidance of Ye. M. Yuganov [6]. The studies were conducted on a centrifuge located in an aircraft laboratory. During flight in a Kepler parabola weightlessness lasted 25-28 s, and for this time the centrifuge was actuated. It was found that with gravity of 0.28-0.3 unit the positions and nature of animal locomotion (rats and mice) did not differ from those inherent in laboratory conditions. On this basis, a level of 0.3 unit was taken as the minimal effective AG.

In subsequent experiments where bioelectrical activity of the dog's femoral muscles was recorded [7], it was determined that the earliest signs of increased activity, as compared to activity of the muscles in weightlessness, appeared with AG of 0.15 units. Within the range of 0.15-0.28 unit, the magnitude of bioelectric potentials increased concurrently with increase in level of gravity. The amplitude characteristics of bioelectrical activity with AG of 0.28-0.31 unit were found to be equivalent to those on the ground. With further increase in AG to 0.6-0.7 unit, no appreciable increase in amplitude of potentials was demonstrable. For this reason, a level of 0.28-0.31 unit was deemed the minimum effective AG.

Interestingly enough, AG of 0.1 unit was sufficient for animals (mice) submitted to bilateral delabyrinthectomy with complete compensation of postoperative motor disorders for preservation of their inherent positions and locomotion [8]. On the basis of these data the hypothesis can be expounded that a level of 0.3 unit, which was set for intact animals, is the minimum for normal function of the vestibular apparatus in a system that provides for the positions and locomotion of an intact animal in a gravity field.

The work done aboard the biosatellites Cosmos-782 and Cosmos-936 during flights lasting up to 20 days constituted development of studies conducted under conditions of brief weightlessness.

In 1975, studies aboard Cosmos-782 on plants and lower vertebrates (fish, turtles) established that the biological effect of 1 unit AG, created with an onboard centrifuge during a long-term space flight, was essentially the same as the effect of earth's gravity [9]. In addition, in the experiments with turtles, a finding was made that can be considered as preliminary [tentative] to the effect that with AG of 0.3 unit none of the atrophic muscle changes inherent in weightlessness is demonstrable. This level coincides with the minimal effective AG for mammals

(rats, mice, dogs), as established in studies with brief weightlessness according to the criterion of normalization of locomotor and postural activity, as well as bioelectrical activity of muscles [6, 7].

Data obtained from the experiments conducted aboard Cosmos-782 served as grounds, for the first time, to consider AG as one of the effective means of preventing the adverse effects on living organisms of prolonged weightlessness.

Studies of the effects of weightlessness and AG of 1 unit on basic vital functions of mammals (rats), involving experiments aboard the biosatellite Cosmos-936, were a continuation of the above-mentioned work.

A comparative analysis revealed that creating AG of 1 unit during space flights made it possible to prevent, to a significant degree, development of nonspecific and specific changes in the organism, which occur under the influence of long-term weightlessness.

Special mention should be made of the normalizing effects of AG on functional state of the myocardium, skeletomusclar system and excretory system. Expressly these systems in man undergo significant changes in function in the presence of weightlessness.

An effort was made under ground-based conditions to define the effective value of AG in studies involving man. Subjects were exposed to the combined effect of hypokinesia and accelerations of $+G_z$ [11-13]. The subjects were rotated for 4 days in horizontal position, with the head toward the center, with accelerations of 0.5-0.6 unit. The great difficulty involved in conducting such studies did not make it possible to have exposure to these factors last long enough, so that a significant preventive effect of accelerations was not demonstrated.

In experiments aboard Cosmos-936, in addition to the generally beneficial effect of AG on the organism, there was rather distinct demonstration of the specific effects of the rotation factor on certain functional systems. Thus, after animals had spent a long time in a system with AG, the following findings were made: diminished reactivity and temporary decrease in sensitivity of the functional system of the semicircular canals [14]; worsening of equilibrium function; lack of turning over reflex and falling when sight was excluded; deterioration of parameters of higher nervous activity [10]; incomplete compensation of changes in the muscular, bone and excretory systems occurring under the influence of weightlessness [15-17]. There is reason to believe that these phenomena are caused by the relatively high speed of the centrifuge (53.5 r/min) and small radius (320 mm).

Some of the specific effects of rotation, which were demonstrated during the experiments aboard Cosmos-936, and, in particular, those related to change in function of the vestibular system, had been noted previously in ground-based studies involving long-term rotation of animals (rats, rabbits) [18-20]. The results of the ground-based experiments also revealed that prolonged stays in rotating systems lead to a change (enhancement) of systemic resistance to a number of physical environmental factors [21-24].

Comprehensive and rather complete evaluation of the influence of the rotation factor on an organism was made in clinicophysiological studies of man during a long-time active stay in a rotating system.

It became possible to conduct such studies after the development of special installations for long-term rotation, in which the subjects could live and work for a rather long time being exposed constantly to the factors caused by rotation.

In the 1960's, two long-term rotating devices were produced in the Soviet Union. The first, the MVK-1 (slowly revolving chamber) has a cylindrical cabin with an axis of rotation that traverses the middle of the floor. The drive of the device provided for uniform rotation at angular velocities of 0,9 to 6.6 r/min [20]. The relatively small size of the cabin (area of about 3 m^2) allowed for no more than two subjects to be in it at one time under minimal conditions of comfort and freedom of movement. For this reason, the stays in the MVK-1 did not exceed 7 successive days [25].

Later on, a more refined device , the Orbit ["Orbita"] stand was used [26]. It was installed on a centrifuge 20 m in diameter. There was a covered passageway along the console, one end of which ended at a habitable cabin about 7 m^2 in size. In this cabin, designed to accomodate 2-3 people who could stay in it continuously for several weeks, comfortable living conditions, including a shower, were provided. In addition, there was equipment in the cabin for observation of the subjects' condition and behavior, as well as to conduct a broad set of clinicophysiological studies. The drive of the centrifuge provided uniform rotation of the device at velocities of 1 to 12 r/min.

All Soviet studies of the effects on man of prolonged stays in rotating systems were conducted using the MVK-1 and Orbit devices. The maximum rate used in these studies was 12 r/min (for 1-2 h) and maximum duration of rotation was 25 days (at rates of 6 r/min) [26].

The very first studies already showed that presence in a rotating system is not indifferent to man. From the very first minutes of rotation, illusory sensations of rotation, vertigo appeared with head movements, there were equilibrium disturbances when moving in the cabin and difficult coordination of movements, which had a large amplitude. After 30-60 min, the following were observed: perspiration, chills or sensation of fever, pallor, intensified salivation, unpleasant sensation in the gastric region, nausea and, in some cases, attacks of vomiting. Later on, after 4-5 h, sleepiness, listlessness and headache were added to the above symptoms.

Thus, during the first few hours in a rotating system there was development of the typical clinical syndrome of motion sickness with its inherent sensory, autonomic and neuropsychological components [26, 27].

Three periods were established for development of motion sickness during prolonged rotation [26, 28]. The first, which lasted 1-2 days, was characterized by progression of intensity of symptoms. As a rule, the vestibulovegetative component was the most prominent. During the second period, which lasted up to 7-8 days, there was gradual, occasionally fluctuating, attenuation of symptoms. First of all, there was attenuation of the nausea syndrome, as a result of which there was prevalence of so-called neuropsychological symptoms (listlessness, headache, scattered attention and others) f the 3d-4th day on. Finally, the third period, which lasted up to 1 mon in the studies [26], was notable for absence of symptoms of motion sickness, and they did not recur, even with additional vestibular stimuli.

The severity of symptoms of motion sickness, as well as time of adaptation to long-term rotation depended primarily on the magnitude of angular rate of rotation.

With rotation at rates of up to 1 r/min, the subjects did not develop any signs of motion sickness. At a rate of 1.8 r/min, when moving the head there was appearance of moderate symptoms of motion sickness, whereas at 3.5 r/min they were marked [20]. In addition, the symptoms were significantly determined by the subjects' motor activity. Moving the head while performing some assignment or other caused (or intensified) symptoms of motion sickness. When head movements were discontinued there was relief, to the extent of total disappearance of symptoms [26]. However, the absence of unpleasant sensations at rest did not mean that adaptation occurred: upon resuming movement the symptoms reappeared [20]. At the same time, head movements aided in development of adaptation to rotation. At rest there are no vestibular stimuli, and for this reason no symptoms of motion sickness appear, but there is also no adaptation to rotation.

In the MVK-1, when freedom of movement was limited, the symptoms of motion sickness were already rather marked at a rate of 1.8 r/min. Greater freedom of movement caused virtually no onset of symptoms of motion sickness with the same velocity of movement [26, 28]. In this cases, the subjects did not sit motionless; they actively and subconsciously controlled movements in such a manner that no unpleasant sensations appeared. One could judge rather objectively the onset of adaptation from the nature and degree of freedom of head movements.

At a rate of 6.6 r/min, there was less distinct adaptation to rotation in the MVK [25] than in the tests with the Orbit device, where there was minimal restriction of freedom of movement [26]. Hence, we can derive an important conclusion: the degree of man's motor activity in a rotating system not only determines the severity of symptoms of motion sickness, but has an appreciable influence on formation of adaptation to rotation, and it can serve as a criterion of its occurrence [26].

The existence of a distinct link between the manifestations of motion sickness and motor activity controlled by the subjects themselves had some influence on the severity of the symptoms related to rate of rotation and initial predisposition for motion sickness. Thus, at rates of 4 and 6 r/min, there were no appreciable differences between individuals differing in predisposition with regard to symptomatology of motion sickness [26].

In the studies involving prolonged rotation, much attention was devoted to the functional state of the analyzers and other physiological systems of the organism. The objective of these studies was to determine man's endurance of long stays in rotating systems and investigate processes of adaptation to accelerations arising during rotation.

It was established that precession accelerations [2] that occur with head movement in a rotating system are the main factor with adverse effects on man's well-being and fitness. Precession accelerations are adequate stimuli for the receptors of the semicircular canals of the vestibular system. With active movements of the head, the subjects developed illusions of rotation or rocking and vestibular nystagmus [20, 26, 28]. As adaptation to living conditions in a rotating system developed, these reactions were attenuated and then disappeared [25].

Enudrance of repeated vestibular stimuli diminished distinctly in the first 1-2 days of rotation; by the 5th-10th day it reached base values, and increased by 3-5 times thereafter, as compared to the background [26, 28].

These data warrant consideration of vestibular reactions as informative enough indicators of adaptation to rotation. At the same time, only partial conformity was demonstrated between endurance of prolonged rotation and initial resistance to recurrent vestibular stimuli as determined by traditional methods [29].

The demonstrated changes in hearing [30] were probably determined more by the long-term effect of noise that the specific influence of accelerations.

A large volume of studies dealt with the functional state of the cardiovascular and other systems that are involved, to some extent or other, in development of vestibulovegetative disturbances.

The observed changes in functional state of the cardiovascular system did not exceed the physiological range [16, 28], even in cases of a marked motion sickness syndrome [31]. In the presence of this sickness, there was prevalence of parasympathetic reflex influence and in the absence of symptoms (after adaptation to rotation) of sympathetic reflex influence. Use of functional tests with a physical load in the presence of moderate signs of motion sickness revealed, in a number of cases, attenuation or even distortion of reactions of the cardiovascular system [32, 33]. Nevertheless, vestibulocardiac reactions apparently cannot serve as a reliable criterion of endurance of prolonged rotation [31].

Special ophthalmological methods were used to assess circulation in the system of the internal carotid [34, 35]. At the early stage of prolonged rotation there was some elevation of diastolic pressure in the central artery (pressure drop in case of marked symptoms of motion sickness) and dilatation of the central vein of the retina. These changes, like the parameters of systemic hemodynamics, did not exceed the physiological range, and they had a tendency toward diminishing with development of adaptation to rotation.

Some subjects presented some neurological signs of vegetovascular dysfunction, which had a tendency toward increase with increase in duration of rotation [26]. This is most probably related to moderate general asthenization of a man spending a long time in a restricted space.

Electroencephalographic examination revealed signs of interhemispheric asymmetry and diminished reactivity in functional tests [25]. There were no appreciable disturbances in the falling asleep process or depth of sleep during long-term rotation. Moreover, sleep had a beneficial effect on well-being [36].

Efficiency [fitness], as rated by the quality of performing research programs, diminished somewhat during the first 1-2 days of rotation due to the presence at this time of symptoms of motion sickness. However, even in the presence of a marked syndrome of motion sickness, all of the assignments were completed [25, 26]. Special techniques [37] revealed some worsening of operator performance. No impairment of short-term verbal memory was observed.

Some changes in blood, which were demonstrated in subjects, consisted of moderate eosinopenia and lymphopenia, as well as decrease in epinephrine-like substances at the early stage of rotation, with subsequent normalization of these parameters [26, 28, 38]. The phasic nature of the observed changes, which coincided with the dynamics of the syndrome of motion sickness, as well as reactions of the cardiovascular system, can be interpreted as a reflection of changes in the adrenosympathetic system.

Much attention was devoted to studies of equilibrium function during long-term rotation. Impairment of equilibrium and accuracy of movements, which were made with wide amplitude, was noted from the first minutes in a rotating system [26, 28] and reached a maximum almost immediately [39]. The severity thereof was directly related to the angular rate of rotation.

At a rate of 4 r/min, the disturbances referable to equilibrium disappeared, according to clinical signs, by the 6th-8th day of rotation; however, normalization of stabilographic parameters occurred only on the 10th-12th day. At 6 r/min, a moderate elevation of stabilographic parameters persisted to the end of the period of rotation.

It is important to mention the change in the role of vision in retaining equilibrium in vertical position [39]. At the start of rotation, when the equilibrium disturbances were the most marked, vision did not improve the ability to retain equilibrium: the stabilographic readings were the same when testing subjects with their eyes open and closed. Subsequently, as adaptation to rotation progressed, the role of vision in postural equilibrium was more significant than under ordinary conditions, and this was demonstrable to the end of the period of prolonged rotation.

As shown by the results of all of the studies, aftereffect reactions after termination of rotation for any period of time were always less marked than at the first period of rotation [25, 29]. It was established that the symptoms of motion sickness persisted for 1-2 days, while changes in vestibular excitability were observed at later times after rotation for up to 3 days [20, 29]. In the case of long-term rotation for over 8 days, there were virtually no symptoms of motion sickness in the aftereffect period. There was prevalence of disturbances referable to coordination of movements and equilibrium when walking, as well as vertigo, which persisted for several hours without worsening the subjects' general condition.

Similar aftereffect reactions were observed in the cardiovascular system [35], equilibrium function [39] and other physiological systems. Normalization of all tested functions occurred within the first 2 days after stopping rotation. Heightened resistance to recurrent vestibular stimuli persisted for at least 2 weeks [26].

These data indicate that extending the time spent by man in a rotating system not only failed to worsen the course of the recovery period, but alleviated it substantially.

Thus, Soviet studies pursued on ground-based installations for prolonged rotation revealed that man can live and work in rotating systems for a long time. The adverse effect of rotation was manifested chiefly in the form of development of motion sickness. In essence, this is what determines man's tolerance of prolonged rotation. The changes in various physiological systems were functional and reversible, and in most cases they were also related to the syndrome of motion sickness. It was established that man can adjust to rotating systems when the rates are up to 6 r/min. The most important criteria of adaptation are the absence of symptoms of motion sickness, normalization of voluntary motor activity, absence of sensory and somatic reactions of vestibular genesis upon moving the head, heightened resistance to recurrent vestibular stimuli, normalization or appreciable reduction of equilibrium disturbances.

Analysis of the Soviet literature dealing with the effects of long-term rotation on man shows that, in spite of the quite large number of publications on this subject, the facts on which they are based were obtained from 8 studies involving 16 people (rotation lasting 1 week to 1 month). At the same time, the rotation factor imposes a most substantial restriction (from the medical point of view) on the choice of AG parameters. For this reason, studies must be continued in this direction.

As a result of studies conducted to date, the values of the two main parameters of systems with AG have been determined: maximum angular velocity--6 r/min, and minimum gravity--0.3 unit [26, 40]. At this rate of rotation and gravity, the radius of rotation of the system would be about 10 m.

From the biomedical point of view, there has been rather broad validation of the rate of rotation of systems with AG in ground-based studies. Substantiation of the minimum gravity level appears less convincing. In this regard, at the present stage of development of the problem of creating systems with AG, the main objective of biomedical studies should be considered determination of minimum AG in long-term space flights at which prolonged weightlessness would not have an adverse effect on the organism. One should choose parameters of the state of the cardiovascular, skeletomuscular and other systems, in which the adverse effects of weightlessness are the most distinctly demonstrable, as criteria of effectiveness of gravity level.

Determination of minimum AG in flight studies makes it possible to adjust the maximum permissible rate of rotation (6 r/min) determined in earth-based studies. Indeed, it may turn out that, with AG below earth's gravity, there will be a change in resistance to vestibular stimuli. A change in permissible angular rate of rotatation at the selected AG level would lead to a change in radius of rotation of the system. As shown by estimates on the assumption that, with decrease in gravity, the threshold sensitivity to vestibular stimuli increases linearly (i.e., it is governed by the Weber-Fechner law), to create AG below earth's gravity the radius of rotation of the system should be increased, rather than decreased, as compared to the radius with AG of 1 unit [41]. Just how true this hypothesis is for AG below earth's gravity will be determined in future studies. At present, it can merely be noted that it is valid for hypergravity. Thus, we established in ground-based studies that, when gravity increases from 1 to 2 units, there is a decrease in severity of symptoms of motion sickness.

In addition to the main task, with regard to AG (determination of minimum effective level of AG), there are several important practical problems of a more special nature, the experimental solution of which can be obtained both during space flights and in ground-based studies involving both man and animals [42].

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COSMONAUTICS AND DEVELOPMENT OF AVIATION MEDICINE

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[Article by N. M. Rudnyy and A. A. Gyurdzhian, submitted 30 Oct 80]

[English abstract from source] The paper discusses certain aspects of interaction between aviation and space medicine, contribution of aviation medicine into the development of space biology and medicine, and the role of cosmonautics in current achievements of aviation medicine. The paper describes advances in studies of space flight effects, development of life support and flight safety systems, medical and psychological support of the flight personnel, implementation of new methods and techniques, electronics, computers and automatics. Particular importance is attached to the rapid development of ergonomic approaches to the design and application of new technology, study of psychophysiology and psychology of human efficient activity in the system "man-flying vehicle-environment," i.e., psychophysiological ergonomics. Certain methodological and organizational aspects of the development of aviation and space medicine are briefly described.

[Text] Manned flights into space were the logical result of progress in space rocket technology, basic and applied research, including research in the field of biology and medicine. Aviation medicine was the forerunner of space biology and space medicine. Thus, aviation was the cradle of cosmonautics, while aviation medicine was the cradle of space biology and medicine.

The solid theoretical and practical (methodological) material accumulated by aviation medicine in the course of studies of the main factors of flight, development of life support and flight safety systems, screening and training of flight crews, medical monitoring of their health status constituted the main foundation for inception and development of space medicine. As far back as the mid 1930's, the leading specialists in Soviet physiology and medicine formulated the principal biomedical problems of aviation, stratospheric and space flights [1]. The first specialists in space medicine were aviation physicians. All this enabled our medicine to become immediately involved in space research and keep up with its rapid pace.

However, the second aspect of interaction between space and aviation medicine is equally important: space medicine, which was born on the basis of aviation medicine,

itself became the strongest and most effective stimulus for progress in aviation medicine and the entire set of biomedical disciplines involved in creating it.

Space medicine, which is called upon to participate in one of the advanced sectors of modern progress--cosmonautics, was able to enlist the collaboration of representatives of the most varied disciplines referable to science and technology, medicine and biology, and social psychology. This enriched space (and, at the same time, aviation) medicine with new theoretical aspects and prospects, practical and methodological opportunities.

Studies of the effects on an organism of various flight factors were conducted by space medicine more deeply and over a considerably broader range than had been done before. If we consider the problem of effects of inertial and gravity forces on the organism, we shall see that this factor was studied in a range that goes from complete weightlessness to chronic and multiple exposure to hypergravity, from low accelerations to high impact accelerations that the crew encounters or could encounter in the case of emergency exit from a flight vechile, parachute opening and landing. Studies were made of the effects of accelerations in different directions in relation to the axis of the body, including accelerations of changing direction and angular ones. Physiological, morphological, biochemical and other methods were used for these studies. The results of this work made it possible to construct a rather orderly conception of gravity physiology, to define the permissible and optimal parameters and modes of gravity factors, to develop the means of protection against their deleterious effects and to assure optimum conditions for the life and effective performance of crews. All this is of first and foremost significance to aviation medicine as well.

Systematic and in-depth studies of the effects of other flight factors were just as fruitful to aviation medicine; we refer to vibration, noise, altered barometric pressure and gas composition in the cabin, ionizing and nonionizing radiation, various temperature modes, humidity and illumination. In particular, the study of problems of space radiobiology, the biological effects of electromagnetic and corpuscular forms of radiation is quite important to assure the radiation safety of flights of modern aircraft.

Formulation by space medicine of the problem of associated and combined effects of several flight factors, which often cannot be anticipated or understood, on the basis of the results of studying different elements of combinations, merits special attention. The unusual physiological effects of changing from the accelerations during the powered flights of rockets to complete weightlessness of orbital flight, which were discovered already in the experiment with the dog, Layka, as well as analogous phenomena observed in subsequent flights, were explained from the methodological vantage points of Soviet physiology concerning the systemic nature of reactions of an organism as an integral whole to exogenous factors. We encounter such phenomena in aviation medicine in some cases when determining the effects of noise, vibrations, accelerations and other factors on the well-being and fitness of flight personnel. These studies made it possible to raise the medical engineering specifications for new aviation technology.

Equally useful was the interaction between aviation and space medicine in the area of developing the means for optimum conditions for the life and efficient performance of crews, and for safety of flights. Here, it is important to mention the development of new promising sources of oxygen, refinement of oxygen breathing

equipment, space suits, helmets, anti-gravity and altitude suits, chairs, special clothing, strapping systems, emergency systems for abandoning flight vehicles, parachuting, landing and autonomous existence, systems for the search and rescue of accident victims. Work on artificial habitats [environments] deepened our knowledge about the biosphere and contributed much to the solution of problems of habitability of residential and work quarters; it enabled us to formulate the main sanitary and hygienic requirements of the gas environment and work place, as well as to define the methods for protection against deleterious and toxic factors.

Many new materials (in particular, synthetic ones) were used in progressive space technology, and this required ongoing studies of their possible toxic properties. Finally, systemic studies were pursued in space medicine of the question of nutrition and water supply for crews, metabolism in flight and under various extreme conditions. The need for cosmonauts to spend a long time in closed and small spaces made it necessary to study problems of space immunology and microbiology, and some valuable information was obtained in these areas. The results of these studies are of equal interest to aviation medicine, public health, sanitation and hygiene.

The results of studies of psychology and efficiency of flight crew performance, use of a broad ergonomic approach to the problem of optimizing the man-machine, man-aircraft system were the most impressive in the field of aviation medicine in the last two decades. Cosmonautics and space medicine deserve much credit in this respect.

Space technology developed with meticulous consideration of man's psychophysiological capabilities and his physiological and hygienic needs. Along with engineers and designers, physicians, psychologists and future cosmonauts themselves participated in developing flight vehicles, life support systems, displays of flight parameters and control systems. This progressive ergonomic principle of medical and psychological involvement in new technology had a beneficial effect on development of both aviation and aviation medicine. At present too, consideration of anthropometric, physiological-hygienic and engineering psychological parameters, as well as systems of medical and psychological involvement in new technology, the so-called conception of engineering psychological design, are an immutable law of modern aviation. This leads to substantial improvement of the cabin, work place, environment, systems for display and control of psychophysiological parameters and capabilities of crews, as well as professional tasks facing them.

The same can be said about studies of the efficiency and optimization of performance of flight crews in the man-aircraft system. The systemic consideration of human traits makes it possible to bring to life the conception of designing work performance [2] for flight crews under different conditions and in different flight modes, i.e., to develop optimum work algorithms.

Thus, fundamental development of the "human factor" and its role in design, as well as for effective and safe operation of aviation and space technology, i.e., development of psychophysiological ergonomics [3, 4], is to be equally credited to both aviation and space medicine.

Physicians and psychologists were confronted with the problem of proper distribution of duties between man and machine by the need for broad use of automation in cosmonautics for the purpose of processing numerous data (in particular, about flight

parameters), decision making and issuing commands of execution. Here, some purely psychological tasks emerged: on the one hand, machines relieve man of an enormous amount of back-breaking routine work, whereas on the other hand excessive automation and removing the pilot or cosmonaut from active and initiative control actions, receipt of information about parameters and the main specifications of the flight could have an adverse effect on his morale and emotional state, self-confidence, proper progress of the mission and successful performance of assignments. It is quite obvious that this problem is also equally important to both space and aviation medicine.

Intensive studies of work done by the crews of spacecraft under extreme conditions deepened conceptions of psychoemotional stress, tension and fatigue caused by professional work, principles for setting standards of flight load, work and rest schedules.

The unique conditions of alternation of "day" and "night" during space flights made it necessary to conduct systematic physiological and psychophysiological studies of the effects of circadian rhythms on crew efficiency and resulted in the rapid development of biorhythmology. For this reason, much work has been done in recent tim s to settle such an important problem to aviation as the effect of transmeridional flights and the desynchronosis they cause on the body. As a result of relevant investigations, the f ight schedules of aviation crews and conditions under which they rest at intermediate stops were optimized; recommendations were elaborated that facilitate the crews' and passengers' adaptation to the physical rhythm of day and night at their destinations.

Studies in the field of space medicine, which were pursued in anechoic pressure chambers with some subjects and small groups of individuals disclosed many of the psychological distinctions of long stays and performance of operators under conditions of social and physical isolation, limited information, stimuli and motor activity; they made it possible to investigate the distinctions of professional interaction and psychological compatibility of different crew members. These studies, along with those of aviation physicians and psychologists on similar issues, resulted in elaboration of recommendations to upgrade the psychological support of flight crews, optimum manning of crews with due consideration of psychological distinctions of their members and optimization of distribution of duties among them.

As we have already noted above, space medicine succeeded in involving many different specialists in their work: engineers, biologists, clinicians, psychologists and others. This made it possible to advance to a new, higher level of methodological armamentarium of research. Space medicine, together with specialists of allied disciplines, developed miniaturized electronic equipment for automatic recording of the main physiological, psychological and hygienic parameters, biotelemetric transmission of information, automatic processing, memory and diagnostics. As a result, we are now able to implement, directly in flight, medical monitoring of the physiological and mental state of aviation crews, as well as some aspects of the quality of their professional performance, in particular, control operations.

The new methodological and technical resources opened the way for modeling and studying on these models the algorithms of different forms of work, physiological and psychological states. Wide use is being made of electronic computer technology.

Various high-speed methods have been developed for clinical and, in particular biochemical tests. The studies conducted in space and aviation medicine, which supplement and enrich one another, together serve for the development of our Soviet public health, in particular, clinical medicine, industrial physiology and sports.

The practical problems confronting space medicine aided in rather intensive and fruitful studies of a number of the body's systems. For example, there have been in-depth and comprehensive studies of morphology, physiology and pathology of the vestibular system, corresponding nuclei and conduction pathways in the central nervous system; there has been considerable broadening of our knowledge about the physiological mechanisms of spatial orientation and equilibrium, causes and mechanisms of disturbances thereof; there has been considerable progress in the study of distinctions of energy and fluid-electrolyte metabolism under altered gravity conditions. Of course, we could continue with the list of research conducted in space medicine that was also important to aviation and clinical medicine.

Space medicine made extensive use of numerous research units and simulators that were furnished by industry. Various methods and systems of general physical and professional training and conditioning were developed and tested with the help of flight training methodologists and sports medicine specialists. This knowhow is also relevant to aviation medicine. We should mention that, in this respect, aviation medicine has rather good practical experience and theoretical substantiation. At the present time, aviation physicians, along with flight training specialists, are involved in working out programs for simulator and flight training, monitoring the physical condition of flight personnel in training and level of their professional readiness according to specific physiological and psychological parameters.

Space medicine has done much work in the area of psychological screening of cosmonaut candidates. Much was done in the area of theory and practice of screening in aviation and solving problems of professional screening in general (with regard to refinement of tests, criteria of normalcy, pathology and professional suitability for different types of work in aviation and cosmonautics).

Space medicine made a ponderable contribution to development and refinement of methods of periodic medical certification of flight personnel, systematic medical monitoring, observation and support of flight, engineering and technical personnel.

It is important to mention that such an advanced, rapidly developing area of human endeavor, which is on the border of many scientific disciplines, as cosmonautics confronted space medicine with new and unexpected problems, which required unusual approaches, nonstandard thinking, involvement of representatives of other specialties for operational solutions, and this could not help but have a beneficial effect on the growth of qualifications of personnel. The problems that are being solved by space medicine constitute a remarkable dialectical integration of practical, applied significance and great theoretical interest, from the standpoint of progress in the basic sciences.

The following general biological problems of utmost importance have been put to space medicine: study of the possibility of life of man, animals and other organisms formed in the earth's ecosphere, during space flights (ecophysiology); determination of forms of life in cosmic space and heavenly bodies (exobiology); demonstration of the routes and moving factors of biological evolution, in particular, the study of the role of gravity and cosmic radiation in evolution.

The combination of theory and practice provides space medicine with the exceptionally beneficial methodological opportunity of testing the validity of its theoretical formulations. For example, the successful development of the artificial environment of the habitable cabin of space flight vehicles was the best practical criterion of the accuracy of our knowledge about the biosphere, correlations between organisms and the environment of their habitat.

Finally, space medicine enriched aviation medicine with regard to the optimum combinations of laboratory and test unit studies, on the one hand, with final flight tests and subsequent analysis and synthesis of results obtained from each, on the other hand. This was an important problem from the standpoint of scientific methodology and economics.

From the day of its inception, space medicine has worked in close collaboration with aviation medicine. Most of the problems they solve are of mutual interest. For this reason, all investigations are coordinated and, in most cases, conducted together. This is how it has been for the last 20 years, and this is how it should be in the future. In particular, they will have to solve problems of medical support, development and operation of air and space flight vehicles.

In the last two decades, aviation medicine, in turn, has made considerable strides, it was theoretically and practically enriched and advanced to a new, higher step. Special emphasis must be laid on the fact that future progress of space and aerospace medicine is possible only if there is constant strengthening of creative contact with representatives of clinical medicine, general pathology and public health.

For the 20th anniversay of the flight of Yuriy Alekseyevich Gagarin, researchers working in the field of aviation medicine send their congratulations to workers in space medicine, and wish to express their confidence in continued development of collaboration between these two disciplines in the interests of progress in Soviet aviation, cosmonautics and medicines, for the sake of implementation of the plans of the 26th CPSU Congress.

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EXPERIMENTAL AND GENERAL THEORETICAL RESEARCH

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CIRCADIAN BIORHYTHMS AND FLIGHT PLANNING

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[Article by A. A. Yurchenko, submitted 6 Apr 79]

[English abstract from source] It has been shown that circadian rhythms of functional systems of the human body exert a noticeable effect on psychophysiology and reliability parameters of pilots and cadets which may be of special importance in flights on a shift basis. The dysbalance in work-rest cycles and circadian biorhythms decreases strongly qualitative and quantitative indices of pilot activities. In some cases this may cause erroneous actions, contingent situations and accidents.

[Text] The increased nervous and emotional loads related to introduction of new aviation technology make it increasingly urgent to study the effects of circadian rhythms on adaptation of cadets and pilots to professional factors.

Mutual desynchronization of work and biological rhythms often leads to a state of tension and stress, which create conditions for development of somatic pathology, on the one hand, and which are factors that affect the efficiency of professional performance, on the other.

In this regard, studies of the distinctions of organizing flight work in shifts play an important role in achieving the main task of aviation medicine, that of preserving the health of flight personnel and assuring the safety of flights.

Methods

A complex study was conducted of the influence of work in shifts on the dynamics of some physiological parameters and psychophysiological reactions. A total of 350 pilots (cadets and instructors) working on the first and second shift were examined. The conditions and methods were identical. The schedule (periodicity) of work cycles (flights) and time off (sleep at night) are illustrated in Figure 1. The subjects retired at 2030 hours and got up at 0430 hours for the first shift. First shift flights started at 0700 hours to 1300 hours (6 h take-off time). Before the second shift, they retired at 2230 hours got up at 0730 hours and flights took of at 1400 to 2000 hours.

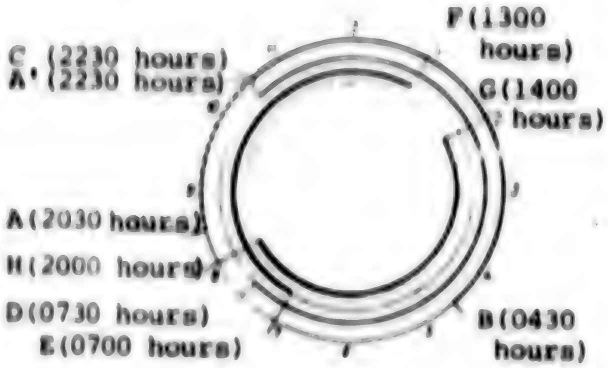

Figure 1.
Chart of work and rest (sleep at night) schedule with two-shift work

A-B) scheduled sleeping time before first shift
A'-B) actual sleeping time before first shift
C-D) sleep before second shift
E-F) flying time on first shift
G-H) flying time on second shift

We recorded the results of the cancellation test, parameters of flight task performance (logs of flight operation officers, barospidograms [typo for baro-pirograms?], spirograms?], tapes of radiocommunications, subjective reactions to shift work).

Results and Discussion

According to the data from the questionnaires, which supplement substantially the methods of examining physiological functions, 73% of the flight instructors prefer to work on the first shift, 6% on the second and 21% have the same attitude toward both shifts. The preference for the first shift is attributable mainly to the large reserve of free time (rest time) after the flights. In most cases, the quality of rest is determined by the duration and quality of sleep [1, 2]. During the period of flight training, sleep should last at least 8 h. However, the answers to the questionnaire and practice show that this requirement is not met for various reasons, while administrative measures are not effective in this case. Poor living conditions constitute 20% of the causes that prevent the pilots from going to bed (at 2030 hours) before the first shift; 65% of the pilots cannot fall asleep at this time (particularly in the summer). The time required to fall asleep before the first shift increases, with the corresponding decrease in actual sleeping time (by a mean of 2 h), in some cases up to 0430 hours (Figure 2). Impairment of sleep is noted in 100% of the cases, and it is related to exogenous social [3, 4] and physical [5] factors, as well as endogenous factors attributable to the static nature of the customary living stereotype. It is known that mutual discoordination of social and physical circadian rhythm clocks [sensors] in the case of work in shifts and disruption of the sleeping-waking rhythm under such conditions, which cause phasic changes in correlations between biorhythms, consistently result in tension and stress of adaptation systems and appearance of general and specific pathological changes [6, 7]. Practice has shown that adjustment to work in shifts is difficult or totally wanting in part of the flight personnel. Thus, Lager [8] indicates that about 20% of the people are incapable of tolerating the effects of factors related to a shifted circadian rhythm. Such lack of adaptability is manifested not only by subjective symptoms, but somatic disorders. This is probably why 65% of the pilots in our study were in favor of organizing flights on one shift.

Analysis of the answers to the questionnaires for cadets revealed the following: only 2% preferred the first shift, whereas 44% preferred the second. The feeling of fatigue was more marked after the first shift (47%) than the second (11%); 42% of the cadets noticed no difference in well-being. In our opinion, these figures

are indicative of inadequate sleep before the first shift (Figure 2). The graph shows that 64% of the cadets were asleep 1 h after taps before flying on the first shift, and this applied to 96% of those on the second shift. The shorter sleeping time explains the cadets' negative attitude toward flying on the first shift.

Figure 2.
Actual sleeping time before first and second shifts. Striped band shows actual sleep time before second shift and cross-hatched section shows actual sleep time before first shift

A) actual onset of sleep before second shift
B) going to bed before first shift
C) actual onset of sleep before first shift

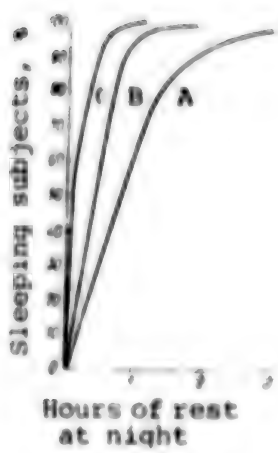

Figure 3.
Curves showing actual falling asleep by cadets

A) before first shift
B) before second shift
C) after second shift

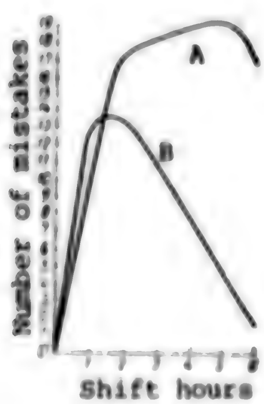

Figure 4.
Distribution of number of errors made during hours of work shift

A) first shift
B) second shift

The difference in opinion as to advantages of work shifts between flight instructors and cadets is attributable to many causes, among which we must single out, first of all, a factor such as the different living conditions of cadets and pilots. While the advantage of the first shift for instructors is determined essentially by the longer free postflight time, such time is just as long for cadets on the first and second shifts. It is strictly set by the schedule for the day. Apparently, the choice by cadets of the second shift is attributable to the opportunity to get more sleep. Disruption of the rhythm not only of work and rest, but of food intake, may emerge as a factor that causes possible impairment of the pilots' psychophysiological functions. As shown by

experience [8], desynchronization of alimentary behavior of a pilot, which is the inevitable consequence of work in shifts, leads to desynchronization of circadian rhythm with regard to levels of biologically active substances and blood sugar. This has an adverse effect on the functional state of the pilot, impairs vigilance and circumspection during flight.

Studies of mistakes, errors that could lead to accidents and quality of flight performance revealed that there are 35% more mistakes on the first shift than the second. The prevalence of mistakes on this shift is related to impairment of attention, and it is directly related to the level of psychophysiological activity, which depends largely on the phase of biorhythm of this function and quality of preflight rest. There is a distinct inverse correlation between the number of mistakes in different shifts and cadets' shift preference. The distribution of mistakes and errors that could lead to flight incidents over different hours of the first and second shifts is also not the same (Figure 4). The decrease in number of mistakes in the 6th h of the flight shift could be explained in part by the fact that there are fewer solo flights by cadets at the end of the shift. The error curve for the second shift has a peak 1-1.5 h after the start of the flights. During the second half of the work shift there is a decline in number of mistakes, which could be due to more effective self-control in the presence of general fatigue at the end of the day.

The results of experimental psychological examinations revealed that there is lower mental productivity on the first shift. The mean time required for the cancellation test was 15.2% longer and number of mistakes was 13.8% greater than on the second shift.

We analyzed all cases of grounding for health reasons over a long period of time. We found that the incidence of grounding is more than double (207%) on the second shift, as compared to the first. The reason for such a significant difference is, in our opinion, that the time of the physical prior to the first shift coincides with the daily minimum for pulse rate and body temperature, and even in the presence of disease (particularly at its early stage) these parameters could remain in the range that is considered normal, conforming with the daytime (but not morning) norm, in these early hours. In practice, the concept of norm does not take into consideration circadian variations, so that there could be cases of failure to detect diseases in the mornings.

Effective medical monitoring requires consideration of circadian fluctuations of functional parameters of the body.

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A MODEL OF FORMATION OF NYSTAGMIC REACTIONS TO A SET OF CALORIC TESTS

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[Article by M. M. Levashov and Ya. A. Bedrov, submitted 29 Oct 79]

[English abstract from source] The model can furnish additional information about the vestibulary system, when evaluating caloric tests. The model has been build with certain assumptions being made. The nystagmus intensity (the slow component rate during maximum intensity) is assumed to be proportional to the difference between energy levels (EL) of the right and left vestibular nuclear complexes (NC). EL of each NC is equal to the afferent flow (AF) plus its inherent activity (IA). During caloric (two warm and two cold) tests IA remains constant. AF at rest is equal to spontaneous activity of receptors and during stimulation it increases or decreases in a linear fashion. Parameters of the model are: difference between intensities of reactions to warm and cold tests, difference between EL of two (right and left) unstimulated NC, and ratio of nystagmus intensity to the stimulus for each labyrinth. The behavior of the model during vestibular dysfunctions of various origin (changes in one of AF characteristics or changes in IA of one NC) is discussed. The diagnostic application of the model is illustrated by the discussion of nystagmometric data. The conclusion about vestibular dysfunction and its etiology can be made on the basis of statistic analysis of parameters of the model in the norm.

[Text] The set that consists of four caloric tests, or the so-called "bithermal caloric test," is a source of valuable information in modern clinical nystagmometry concerning vestibular function [1]. In order to obtain the main diagnostic information, a comparison is made of intensity of nystagmic reactions and two coefficients are calculated: labyrinthine asymmetry and dominant direction. The former is calculated as the ratio of difference in intensity of reactions evoked on the right and left to the sum of four intensities and the latter, as the ratio of difference between reactions directed to the left and right to the same sum.

Our objective was to develop a model that would enable us to gain additional information needed for diagnostics about the state of vestibular function by applying certain formal rules to the results of the caloric tests.

The model can be used for different purposes: to compare "background parameters" to "experimental" ones; to study the dynamics of vestibular function; to demonstrate deviations in professional screening; to assess the efficacy of rehabilitation measures, etc. It is expedient to use the model to define the state of the vestibular system on the level of its receptors, nerve and, in part, the vestibular nuclear complex. In constructing the model, several assumptions were made that were based on systematization of known facts in the field of physiology and pathology of the vestibular system, vestibulocochlear nerve and vestibular nuclear complex [2, 3].

In physiology of the vestibular system, it is popular to make a qualitative analogy between the behavior of afferent conduction upon stimulation of receptors of the semicircular canal and so-called triode characteristics (for more details see [2]). Such approximation has also been used in our model, where it is one of the elements for describing the activity of the vestibular nuclei. Several new properties in the model (for example, a constant component of activity of the nuclear complex, which is not directly related to afferent flow but is involved in formation of nystagmus and mechanisms of compensating vestibular dysfunction), as well as conversion of the model to the "nystagmometric language" and rendering it quantitative by means of statistic description of parameters, made it possible to use the model for diagnostic purposes.

The receptor system of the ampulla of the semicircular canal is viewed as a sensor that reacts proportionately to the magnitude of the cupuloendolymphatic change by altering the intensity of afferentation (AF) [or afferent flow] traveling over the nerve to the vestibular nuclear complex (VN) and involved in formation of the "energy level" (EL) of this complex. On both sides, the EL is made up of AF and a certain intrinsic nuclear activity (IA). The latter remains constant throughout the test. Without the caloric test, AF equals spontaneous activity (AF_{sp}) of the receptor system. During the test, the EL of VN changes because of changes in AF caused by stimulation of the labyrinth.

Caloric nystagmus is believed to be the consequence of creating an EL difference in the right and left VN under the influence of a stimulus delivered to the vestibular system and the consequent change in AF. The intensity of nystagmus, which is measured by the velocity of the slow component (VSC) in the area of culmination of the reaction, is considered to be proportional to the difference between EL of the two VN, while the direction of nystagmus (to the right or left) depends on the side where EL is higher. In the absence of stimulation of the vestibular system, the difference in EL of the two VN may also differ from zero, but this is not necessarily associated with spontaneous nystagmus, i.e., it may not be manifested externally in any way.

It is assumed that the curve of AF as a function of temperature stimulus (heating, cooling) is S-shaped. The assumption is also made that, with ordinary magnitudes of stimuli (±7°C, as compared to body temperature), in a "normal" vestibular system there are cupuloendolymphatic changes, in the presence of which AF as a function of magnitude of the stimulus is linear. In a supine subject, there is an increase in flow under the influence of warmth, i.e., the level rises, as compared to AF_{sp}, whereas cold elicits a decrease in flow by the same amount. It is also assumed that the characteristics are normally identical on the right and left (Figure 1, a).

With these assumptions, the results of the set of caloric tests can be written down as follows in the normal case:

$$N_{rw} = K_r + \Delta \qquad N_{rc} = K_r - \Delta \qquad N_{lw} = K_l - \Delta \qquad N_{lc} = K_l + \Delta \qquad (1)$$

where N is the intensity of caloric nystagmus in warm (w) or cold (c) test on the right (r) or left (l); Δ is the part of intensity of nystagmus due to initially existing difference between EL of right and left VN unrelated to stimulation; K_r and K_l are the coefficients of proportionality between intensity of nystagmus and magnitude of stimulus for the right and left vestibular systems, respectively (the magnitudes of stimuli used are considered to be 1). The latter reflect the steepness of inclination of the linear part of the characteristic.

The information obtained from studying the vestibular system, concerning functional heterogeneity of afferent pathways, as well as correlation between their functional distinctions and topography, warrants the assumption that some afferent pathways should be able to withstand a deleterious factor delivered to different (from the standpoint of morphology) afferent pathways for a longer time than others. Damage to some part of the afferent pathways would lead to a change in the characteristic and its position on the axes of the graph. On this basis, as well as with consideration of clinical observations, the model can be confined to a certain set of variants of "pathology." The proposed set cannot be directly argumented. The following facts serve as indirect arguments. In the first place, this set was found to be sufficient to obtain virtually all the diversity of variants at the output of the model that have been observed in practice in cases of "peripheral" lesions. In the second place, in those cases when the model turned out to be unsuitable to submit conditions under which the obtained result could be formed, a more comprehensive examination with the use of additional tests revealed symptoms of central nervous system lesion, i.e., the level of the lesion was higher.

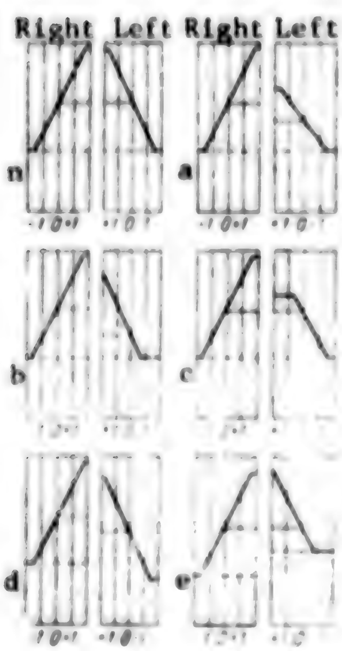

Figure 1.

Correlations between EL of VN under normal (n) conditions and in the presence of some forms of pathology (a-e)
X-axes: deflections of cupula in response to warm (+1) and cold (-1) stimuli; y-axes: VN activity. The scales are arbitrary. The mirrored position of the axes stresses the mutual orientation of receptors. The S-shaped characteristics of AF are situated above the levels of intrinsic activity (IA) shown by dash lines. The EL of each VN equals the sum of IA and AF; without stimulation it is illustrated by the solid horizontal line.
In all instances, pathology is shown on the left:

a) decreased steepness of characteristic and corresponding decrease in AP_{sp}
b) restriction of characteristic "at the bottom," associated with decrease in AP_{sp}
c) restriction of characteristic "at the top"
d) decline of IA level
e) restriction of characteristic "at the bottom" is compensated by redistribution of IA between the two VN

It is assumed that "pathology" consists of a change in some properties (individually or in various combinations), as compared to the "norm" (Figure 1, a-e): change in steepness of characteristic of dependence of AF on magnitude of cupuloendolymphatic

shift (*a*); restriction of characteristic "at the bottom" leading to diminished reaction to cold stimulus (*b*); restriction of characteristic "at the top" associated with diminished reaction to warm stimulus (*c*); change in IA level of VN (*d*).

The following restrictions for items *b* and *c* were added in order to make possible the diagnosis of vestibular pathology from the results of the set of caloric tests within the framework of the model: these types of "pathology" can be present in only one of the labyrinths, and they do not appear simultaneously, i.e., in each case we can assume the presence of only *b* (or only *c*) on one side.* With these restrictions, the results of the caloric tests could be described by the following models in the presence of "pathology":

$$N_{rw} = RK_r + \Delta \qquad N_{rc} = K_r - \Delta \qquad N_{lw} = K_l - \Delta \qquad N_{lc} = K_l + \Delta \tag{2}$$
$$N_{rw} = K_r + \Delta \qquad N_{rc} = K_r - \Delta \qquad N_{lw} = RK_l - \Delta \qquad N_{lc} = K_l + \Delta \tag{3}$$
$$N_{rw} = K_r + \Delta \qquad N_{rc} = RK_r - \Delta \qquad N_{lw} = K_l - \Delta \qquad N_{lc} = K_l + \Delta \tag{4}$$
$$N_{rw} = K_r + \Delta \qquad N_{rc} = K_r - \Delta \qquad N_{lw} = K_l - \Delta \qquad N_{lc} = RK_l + \Delta \tag{5}$$

where $R \leq 1$ is the coefficient describing the degree of deviations of the *b* or *c* type.

The procedure for diagnosing vestibular pathology from the results of caloric tests involves solving two problems. The first is to determine whether, in the case in question, there are any type *b* (or *c*) deviations and, if so, on which side. The answer to this problem determines the choice of one of four possible models, i.e., (2), (3), (4) or (5). The second problem is to determine the values of the parameters of the chosen model.

Parameter M, which corresponds to the coeffficient of effectiveness of caloric stimulation, may be used as a criterion that helps solve the first problem. Let

$$M = \frac{(N_{rw} + N_{lw}) - (N_{rc} + N_{lc})}{(N_{rw} + N_{lw}) + (N_{rc} + N_{lc})} \tag{6}$$

Since K_r, $K_l > 0$ and $R \leq 1$, the following inequalities are valid for the values of criterion M corresponding to models (2), (3), (4) and (5):

$$M_{(2)} = \frac{K_r(R - 1)}{K_r(R + 1) + 2K_l} \leq 0$$

$$M_{(3)} = \frac{K_r(1-R)}{K_r(R + 1) + 2K_l} \geq 0$$

$$M_{(4)} = \frac{K_l(R-1}{K_l(R + 1) + 2K_r} \leq 0$$

$$M_{(5)} = \frac{K_l(1-R)}{K_l(R + 1) + 2\ K_r} \geq 0$$

Consequently, if $M = 0$ there is no pathology of type *b* or *c*; if $M>0$, there is type *b* pathology and if $M<0$ there is type *c* pathology.

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*In order to determine whether the patient presents minimal characteristic steepness or theoretically assumed combination of *b* and *c*, it is sufficient to run additional tests using other temperatures.

Evidently, in each instance the decision of whether one can consider a deviation of some parameter of the model to be indeed pathological should be based on its statistical description. Estimates of the necessary parameters were obtained on the basis of caloric tests on 50 healthy subjects. Table 1 lists the mean arithmetic standard deviations of M calculated with equation (6), as well as the difference between the two VN with regard to EL (Δ) and difference between coefficients of proportionality (K_r, K_l) calculated using formulas (7) given in Table 2.

Table 1. Model parameters obtained from statistical processing of "normal." (Set of caloric tests on 50 healthy subjects, at +30 and +44°C)

Parameter	n	$\bar{x} + \sigma$	"Normal" range at 5% level of significance (according to distributions)
M	50	0.029±0.011	$-0.080 \div 0.160$
Δ	50	-0.46±0.18	±3.0
K_r and K_l	100	22.3±0.55	$13.0 \div 32.0$
$(K_r - K_l)/(K_r + K_l)$	50	0.0064±0.0076	±0.10

Table 2. Formulas for calculating model parameters as a function of value of M and side of lesion

Parameter	M = 0	M ≠ 0, pathology on the right	M ≠ 0, pathology on the left
Δ	$\frac{(N_{rw} + N_{lc}) - (N_{lw} + N_{rc})}{4}$	$\frac{N_{lc} - N_{lw}}{2}$	$\frac{N_{rw} - N_{rc}}{2}$
K_r	$\frac{N_{rw} + N_{rc}}{2}$	$\begin{cases} N_{rw} - \Delta \text{ (with } M>0) \\ N_{rc} + \Delta \text{ (with } M<0) \end{cases}$	$\frac{N_{rw} + N_{rc}}{2}$
K_l	$\frac{N_{lw} + N_{lc}}{2}$	$\frac{N_{lw} + N_{lc}}{2}$	$\begin{cases} N_{lw} + \Delta \text{ (with } M>0) \\ N_{lc} - \Delta \text{ (with } M<0) \end{cases}$
R	No restrictions of characteristic	$\frac{N_{rw} + N_{rc}}{K_r} - 1$	$\frac{N_{lw} + N_{lc}}{K_l} - 1$
	(7)	(8)	(9)

According to the assumptions made in constructing the "normal" model, the distribution of these three parameters should have zero means. The probability of getting the standard deviations listed in Table 2 with zero means constitutes $P_M = 0.014$, $P\Delta = 0.015$ and $P_K = 0.4$, respectively. Consequently the model of the "norm" does not contradict the experimental data on the 1% level of significance. Histograms of distributions of model parameters under "normal" conditions are illustrated in Figure 2.

According to the models of "norm" and "pathology" discussed above, diagnostics of vestibular dysfunction from the results of the caloric tests amounts, in each specific case, to several simple calculations. First one calculates criterion M using equation (6) and, on the basis of comparison to the distribution of this parameter in the "norm," one determines whether the found value of M differs from zero in

accordance with the selected level of significance. For example, with a 5% level of significance, M does not differ from zero if its value is in the range of −0.08 to +0.16.

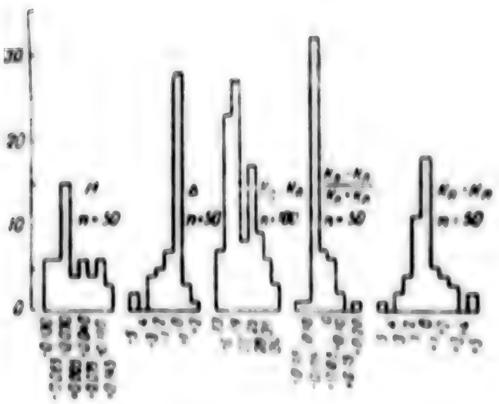

Figure 2.
Histograms of distributions of parameters of the model under "normal" conditions.

X-axis, bottom range of classes; y-axis, frequencies. The size of the three samples was 100 (results of right and left tests combined) and for the others 50. The parameters for the second and third samples were calculated using formulas (7) in Table 2.

M) criterion calculated with equation (6)
Δ) difference between EL of the two VN without stimulation
$K_{\text{П}}$, $K_{\text{Л}}$) coefficients of proportionality reflecting steepness of linear part of characteristic [right, left]
$(K_{\text{П}}-K_{\text{Л}})/(K_{\text{П}}+K_{\text{Л}})$ is relative difference between coefficients of proportionality
$K_{\text{П}}-K_{\text{Л}}$) absolute difference between latter

Note: Russian subscripts П and Л in this figure refer to right and left, respectively

If the hypothesis that M = 0 is not rejected, there is no pathology of type *b* or *c* and parameters Δ, K_r and K_l are estimated in conformity with the model (1) using formulas (7) (see Table 1 [sic]). Then, using the distributions (see Figure 2) obtained for "normal" conditions, a conclusion is made as to presence or absence of pathological deviation for each parameter separately. For example, the relative difference in steepness of characteristic slope does not differ from zero with a 5% level of significance if its value does not exceed the range of ±0.10 (see Table 1 and Figure 2).

In the case where hypothesis M = 0 is rejected, use of additional data is required to select one of the four models, so that one can determine on which side a lesion of type *b* or *c* occurred. These data include, in particular, unilateral impairment of hearing. If the side of the lesion is determined, the parameters of the model are calculated using formulas (8) or (9), which are given in Table 2. When the side of the lesion cannot be determined from indirect data, the choice of one of two model variants is made by means of an additional vestibulometric test. For example, by increasing the intensity of the cold stimulus in an additional caloric test and having not demonstrated an increase in intensity of the reaction that is inherent in a normal labyrinth, one can assume that there is type *b* pathology on the tested side.

We submit below two examples of using the model for diagnostic purposes.

First example: Intensity of reactions in caloric tests:

$N_{rw} = 31.2$ $N_{rc} = 22.3$ $N_{lw} = 9.3$ $N_{lc} = 15.9$

With traditional evaluation of such results, one can obtain three coefficients: labyrinthine asymmetry (LA = +0.36), directional dominance (DD = +0.20) and effectiveness of stimulation (TE = +0.03).

The model makes it possible to define the nature of the pathological process. Since M = TE = +0.03, we can consider that there is no type *b* or *c* pathology. To calculate the parameters of the model, one should use formulas (7) in Table 2. Results of calculations: $\Delta = +3.9$, $K_r = 26.8$, $K_l = 12.6$, $(K_r - K_l)/(K_r + K_l) = +0.36$. Conclusion: depressed function of left labyrinth combined with dominant activity of the right nuclear complex, decompensation. This example is similar to the one illustrated in Figure 1a.

Second example: Intensity of reactions to caloric tests:

$N_{rw} = 31.0$ $N_{rc} = 18.1$ $N_{lw} = 24.4$ $N_{lc} = 18.1$

Vestibulometric coefficients calculated by traditional method: LA = +0.07, DD = +0.07, TE = +0.21. The first two coefficients do not exceed the range of variations observed under normal conditions [1]. The diagnostic meaning of the third has not yet been studied. Consequently, using a formal approach to evaluation of these results, one cannot consider them indicative of pathology in general, let alone of the level or side of lesion. Now let us try to use the model to evaluate this case. Since M is beyond the "normal" range (M = TE = +0.21), we must assume that there is type *b* pathology. Let us imagine that there is no additional information about the side of the lesion. In such cases, one must check two assumptions: that type *b* pathology is on the right or that the same type of pathology is on the left. Using formulas (8) in Table 2 to check the first hypothesis, we get: $\Delta = -3.15$, $K_r = 34.15$, $K_l = 21.25$, $R = 0.43$ and $(K_r - K_l)/(K_r + K_l) = +0.23$. For the second hypothesis, calculation of the same parameters is made using formulas (9): $\Delta = +6.45$, $K_r = 24.55$, $K_l = 30.85$, $R = 0.37$ and $(K_r - K_l)/(K_r + K_l) = -0.11$.

Validity of the first assumption (type *b* pathology on the right) appears doubtful since it must then be assumed that there is concomitant depression of function in the right labyrinth ("shift" of characteristic: R = 0.43) and pathologically heightened reactivity (increased steepness of characteristic, $K_r = 34.15$). It is more logical to assume that there are pathological deviations in the left labyrinth, i.e., to select the parameters obtained with the second assumption. In this variant, steepness of each characteristic (K_r, K_l) does not exceed the "normal" range (see Figure 2), their relative difference is also close to "normal." The pathology amounts to a "shift" of the characteristic of the left labyrinth and, as a consequence, pathological dominance of EL of the right VN ($\Delta = +6.45$), i.e., a difference between the activity of the two VN similar to the one illustrated in Figure 1b. Conclusion: uncompensated decrease in function of the left labyrinth. It remains for us to add that the assumption of left-sided pathology of the *b* type in the case under discussion was confirmed by an additional cold test on the left ear (+20°C), in which the intensity of nystagmus did not differ from that obtained in the main test. Thus, use of the model for diagnostic purposes made it possible to detect vestibular dysfunction on the left, with "peripheral" localization.

Further statistical definition of model parameters will probably result in broadening the area of its applications for diagnostic tests. The model may also turn out to be useful in the didactic respect: graphic reflection of conditions determining

the intensity of caloric nystagmus in the form of correlations between two characteristic graphs helps form an idea about some of the mechanisms of origin of labyrinthine asymmetry and direction dominance of diverse genesis.

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METHODS

UDC: 614.72-07

METHOD FOR CONCENTRATING TRACE IMPURITIES FROM THE ATMOSPHERE OF ISOLATED CHAMBERS BY MEANS OF COOLED TRAPS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 2, Mar-Apr 81 pp 93-94

[Article by T. V. Nol'de, N. M. Vatulya and O. A. Sukhorukov, submitted 27 Feb 78]

[Text] It becomes necessary to assay organic substances present in submicroscopic amounts in the atmosphere when studying various biological systems.

The use of existing instrumentation methods for physicochemical analysis of multicomponent systems, which include both chromatography and mass spectrometry, is limited in the case of direct assay of trace contaminants due to the inadequate sensitivity of the equipment (10^{-5}--10^{-6} vol.%), which obviously cannot satisfy modern requirements for analysis of habitable sealed compartments. For this reason, when studying atmospheric pollution, trace impurities are submitted to preliminary enrichment, either in cooled traps or adsorption concentrator columns, or else thermal methods on chromatographic columns are used for this purpose [1]. Trapping the contaminants, followed by desorption of accumulated compounds when they are heated, is the most popular method for analyzing the atmosphere of sealed habitable compartments [4]. However, the concurrent presence in the atmosphere of a broad spectrum of chemical compounds, which could interact when concentrated, as well as the irreversible adsorption of a number of trace impurities on sorbent, makes it quite difficult to make an analysis using only adsorption techniques for concentration.

In this report, we shall deal with questions of practical use of traps at low temperature for quantitative chromatographic analysis of trace contaminants present in the atmosphere of inhabited sealed spaces.

For this purpose, we used successively connected traps [2], the first of which was cooled to 0°C and the rest to the temperature of dry ice. The different temperature levels of the traps caused preseparation of chemical compounds according to their boiling point and, consequently, they ruled out in part the factor of chemical interaction. Table 1 lists the distribution of some of the compounds studied in the traps. Saturated hydrocarbons were trapped only in the fourth trap; most oxygen-containing impurities and aromatic hydrocarbons were retained in the second trap, which was cooled with dry ice.

In the second series of studies, to increase the effectiveness of trapping the trace contaminants, the third trap was filled with porous fluoroplastic and the fourth with silochrome [?] S-80; consequently, not only did we use the concentration

method in cooled traps, but the adsorption method of trapping. Porous fluoroplastic was chosen because of its chemical inertness and heat resistance. We determined completeness of trapping by means of additional checking of the traps with sorbent (carbon, silica gel). The results of our analysis revealed that only methane was present in the control trap.

Table 1. Distribution of components studied in empty cooled traps, air being passed through the traps for 6 h

Substance	Amount (%) in each trap			
	1	2	3	4
Hexane	—	2.8	1.0	96.2
Heptane	—	7.4	5.5	87.1
Benzene	—	76.2	23.8	—
Toluene	—	73.6	26.4	—
o-Xylene	—	97.2	2.8	—
Methanol	18.4	44.9	36.7	—
Ethanol	5.3	70.0	24.7	—
n-Propanol	1.2	91.8	7.0	—
Isopropanol	1.1	89.7	9.2	—
n-Butanol	2.7	87.3	—	—
Acetone	4.6	24.6	70.8	—
Ethyl acetate	1.0	98.0	1.0	—
Propyl acetate	0.8	99.2	—	—

Table 2. Distribution of low concentrations of toluene and n-propanol in the system of cooled traps

Substance	Concentration at input, vol.%	Total subst. in trap, mg	Amount (%) of substances in traps			
			1st	2d	3d	4th
Toluene	$1.83 \cdot 10^{-6}$	$7.2 \cdot 10^{-3}$	—	54	35	11
	$6.27 \cdot 10^{-7}$	$2.2 \cdot 10^{-3}$	—	34	42	24
n-Propanol	$1.59 \cdot 10^{-6}$	$3.75 \cdot 10^{-3}$	14	85	1	—
	$3.36 \cdot 10^{-7}$	$0.77 \cdot 10^{-3}$	8	92	—	—

Quantitative assays of trapped contaminants were made by means of a diffusion device that permitted continuous delivery of low concentrations of the compounds studied (from 10^{-6} to 10^{-7} vol.%) in the stream of air. The length of the capillaries, through which diffusion occurred, constituted 32 cm and inside diameter was 0.4 mm. To obtain different concentrations, we altered the temperature of the vials with the substance to be examined. We studied the distribution of trace impurities in the traps on the example of n-propanol and toluene. The averaged distribution of toluene and n-propanol in the traps is shown in Table 2.

Table 2 shows that, with decrease in initial concentrations, there is some redistribution of substances in the traps. The overall amount of toluene and n-propanol

concentrated in the traps coincides with the amount of substance fed into the traps with accuracy corresponding to the error factor for preparing low concentrations (±30%).

To shorten the time required for analysis, we tested different rates and time taken to collect samples. We tested 3 to 10 h for collection of samples and the rate of flow of the analyzed gas through the traps ranged from 200 to 500 mℓ/min. On the basis of this work, it was determined that 3-h collection at a rate of 500 mℓ/min and desorption of components from the first two traps at 100°C, and from the others at 200°C were the optimum conditions.

Table 3. Trace impurities demonstrated in the man-chlorella reactor biosystem according to chromatographic data, mg/m³

Substance	18/IV	22/IV	28/IV	8/V
Propylene	—	0.0985	0.173	0.0448
Isobutane	0.0459	0.1028	0.0599	0.0225
n-Butane	0.0513	0.0794	0.1076	0.0362
Isopentane	0.0379	0.0442	0.0715	0.0152
Pentane	0.0930	0.1531	0.3947	0.0941
Heptane	0.0570	0.1600	0.1700	0.0630
Hexane	0.0372	0.0269	0.0263	0.0137
Hexene	0.000	0.0098	0.0101	0.0073
Octane	0.0900	0.0087	0.0040	—
Octene*	0.11'7	0.0286	0.1938	0.0222
Methanol	0.2420	0.8390	0.4450	1.2600
Ethanol	0.4200	1.020	1.680	0.4700
Propanol-I	0.0612	0.0286	0.1660	0.0299
Propanol-II	0.685	0.748	1.080	0.8000
Butanol	0.0485	0.10030	0.0038	—
Isobutanol	0.4610	0.351	0.852	0.381
Benzene	0.366	0.315	0.322	0.235
Toluene	0.0441	0.0618	0.1585	0.0344
Xylene*	0.0038	—	0.0136	0.0074
Acetone	0.0339	0.0346	0.0554	0.0376
Acetaldehyde	0.308	1.050	—	1.170
Propionic aldehyde*	0.324	0.176	—	0.008
Ethyl acetate	0.0074	0.0057	—	0.0079
Butyl acetate	—	0.0547	0.0425	0.0262

*Components that were identified only in one phase.

Analysis of concentrated trace contaminants was made on gas-liquid chromatographs, the Tsvet-106 and Tsvet 4-67, with an ionization-flame detector, on three columns, each 3 m long and with 3 mm inside diameter, with the following phases: 20% diethylene glycol succinate on chromosorb W-AW 60-80 mesh; 20% dioctyl phthalate on chromosorb [kieselguhr] W-AW 60-80 mesh; 15% squalene on Celite 545 AW 80-100 mesh. In the isothermic mode the column temperature was 80°C and velocity of carrier gas (helium) was 30-44 mℓ/min.

This method was used to examine the levels of trace impurities in the atmosphere of a model of a biological life support system, that was sealed for gas exchange, fluid metabolism [or exchange] and, in part, for biogenous elements [3]. Direct

chromatography of air samples from a system based on photosynthesis of chlorella cultivated together with concomitant microorganisms and activity of microflora, which performs biological mineralization of urine, makes it possible to demonstrate no more than 3-4 components. With the use of the described method, of concentration in cooled traps, we demonstrated 35 components of impurities, 24 of which were identified. The results of this analysis are listed in Table 3.

The proposed method can be used to study the dynamics of accumulation of various trace impurities, sources of pollution of the atmosphere of a given space, characteristics of resistance [stability] of bioregenerative processes and state of the entire system under study as a whole.

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ANNIVERSARIES

UDC: 613.693:929 Komendantov

GEORGIY LEONIDOVICH KOMENDANTOV (ON HIS 70TH BIRTHDAY)

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 2, Mar-Apr 81 p 95

[Article by editorial board]

[Text] Prof Georgiy Leonidovich Komendatov, doctor of medical sciences, recipient of the USSR State Price and head of the department of aviation and space medicine at the Central Institute for Advanced Training of Physicians, celebrated his 70th birthday and 49th year of scientific and public work.

G. L. Komendantov is an outstanding specialist in the field of aviation medicine. He has trained many scientists and aviation physicians, both in our country and in several foreign countries.

G. L. Komendantov had his scientific training through graduate studies in the department of physiology of the Military Medical Academy imeni S. M. Kirov, under the guidance of Academician L. A. Orbeli. He defended his candidatorial dissertation on the subject of "Physiological Mechanisms of Labyrinthine Reflexes" in 1940, and his doctoral one on "Righting Reflexes" in 1964. After completing his graduate studies, Georgiy Leonidovich remained as a teacher in the department of physiology of the Military Medical "Order of Lenin" Academy imeni S. M. Kirov.

During the years of the Great Patriotic War, G. L. Komendantov participated in the defense of Leningrad. At that time, he worked in a surgical clinic and conducted research dealing with problems of medical support of military aviation missions.

Georgiy Leonidovich is a brilliant experimenter, organizer of complicated scientific research and educator of scientific and pedagogic cadres. A total of 29 candidatorial and doctoral dissertations were defended under his supervision. He made a substantial contribution to work on the following scientific problems: pilot rescue in emergencies; spatial orientation during flights; equilibrium function under ordinary and extreme conditions; accelerations in aviation medicine; motion sickness; optimization of postgraduate advanced training of aviation physicians.

For the last 20 years, G. L. Komendantov has headed the chair of aviation medicine of the Central "Order of Lenin" Institute for Advanced Training of Physicians.

The vast pedagogic experience of G. L. Komendatov made it possible to achieve very good results in educational and methodological work in the department, and to

organize (together with the department of aviation medicine of the Military Medical "Order of Lenin" Academy imeni Kirov) regular symposiums of the Moscow and Leningrad sections of aerospace medicine for optimization of the pedagogic process.

The encylopedic erudition and organizing talent of Georgiy Leonidovich enabled him to assume a guiding role in convening in the department annual symposiums dealing with such pressing problems of aviation medicine as "Means of Upgrading Preflight Medical Checkups," "Special Functional Diagnostics--Future Direction of Medical Certification of Flight Personnel," "The Problem of Motion Sickness," and others.

The high-level scientific demands that G. L. Komendantov made of himself, his sensitivity and kindness, combined with party-mindedness, earned for him much authority among pedagogues, scientists and aviation physicians, both in our country and abroad.

Georgiy Leonidovich is very busy with public service: for many years he has been the deputy chairman of the section of aviation and space medicine of the Moscow Physiological Society, a member of a specialized committee for the defense of doctoral dissertations at the Institute of Biomedical Problems; he is a member of the board of the Central "Order of Lenin" Institute for Advanced Training of Physicians and of the medical council of the Ministry of Civil Aviation.

G. L. Komendantov is an avid disseminator of information about aviation medicine. He is a regular speaker on behalf of the All-Union "Znaniye" Society for flight personnel and aviation physicians.

For his services to his homeland, the orders of the Red Banner and Red Star, as well as medals "For Combat Service," "For the Defense of Leningrad," "For the Victory Over Germany" and others have been bestowed upon G. L. Komendantov.

Pedagogues, scientists, scientific coworkers, aviation physicians and specialists--members of the section of aviation and space medicine of the Moscow Society of Physiologists, offer their warm and cordial congratulations to Georgiy Leonidovich on his birthday, and wish him good health, happiness, many more years and new creative achievements for the good of our beloved Homeland.

ABSTRACTS OF ARTICLES FILED WITH THE ALL-UNION SCIENTIFIC RESEARCH INSTITUTE OF MEDICAL AND MEDICOTECHNICAL INFORMATION

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 2, Mar-Apr 81 p 96

[Abstracts]

UDC: 616-001.12

[Text] "Roentgenological and Pathoanatomical Studies of the Bone and Joint System of Dogs After Exposure to High and Low Pressure," by R. T. Kazakova, V. V. Panikarovskiy, A. S. Grigor'yan and Z. P. Antipova

A study was made of the effects of high and low pressure on the bone and joint system of dogs. A total of 137 studies were conducted on two dogs for 6 years, with six interruptions of different duration (3 to 12 months). At first, the animals were kept in an RKM-2 chamber with air at different pressure levels [from 0.5 to 1.8 atm(gage)] for 5 h. Immediately after exposure to high pressure, the dogs were "lifted" in an oxygen chamber to an "altitude" of 10,000 m at the rate of 25 m/s and kept there for 2.5 h. Appearance of the bends or worsening of general condition served as the criterion of occurrence of decompression disorders (DD). When DD cccurred after exposure to high pressure or did not go away after exposure to low pressure, therapeutic recompression. Two dogs (control) were kept under the ordinary vivarium conditions.

After sacrificing the four dogs by injecting a lethal dose of anesthetic, bone and joint tissue was submitted to morphological examination. The results revealed that there were negligible dystrophic changes, characterized by pyknosis and lysis of cartilage cell nuclei, attenuation of basophilia of the ground substance of cartilage in the cartilage plates of articular surfaces of the femur and tibia. In some sections of the articular surface of the head of the femur, in the region of the hip joint, there was dilatation of the cavity of fibrous tissue, apparently replacing cartilaginous tissue. In addition, in the region of the articular head of the femur there was some widening of the transitional zone between the cartilage and bone tissue, with total absence of this zone in the tibia, in some cases. Cartilage-like structures in the presence of some mucoidization of intercellular substance were found in the meniscus of the knee. The changes were insignificant in bone tissue and were referable mainly to architectonics of osseous structures. There was some dilatation of the system of nutrient canals in the compact bone of the diaphyses and enlargement of the medullary spaces of metaphysial spongy bone, associated with thinning of osseous trabeculae. However, the absence of changes in configuration and number of lines of adhesion indicates that osseous tissues of animals involved in this study did not undergo gross structural changes or related reactive transformations.

In our studies, DD that occurred at a high "altitude" usually disappeared after "descending" to "ground" level. However, in the case of numerous repeated "ascents," the bends recurred, confirming the presence of "silent" gas bubbles in the organism for a long period of time (3-8 h). According to data in the literature, "silent" gas bubbles may cause osseous infarctions and myodegeneration of the heart (without clinical symptoms) in people submitted to decompression for a long time. The morphological changes described above in bone and cartilage structures of the bones studied could be interpreted as the consequence of the effects of the "silent" gas bubbles, which did not elicit irreversible destructive changes under our experimental conditions.

UDC: 612.28-06:612.273.2.017.2

"Changes in Regulation of Respiration During Adaptation to Hypoxia," by Ye. P. Gora

A study was made of individual distinctions of regulation of human respiration in the course of adaptation to altitude hypoxia. Three series of tests were conducted with different modes of exposure to acute (h = 5000 m) and chronic (h = 4200 and 3500 m) hypoxia. We used functional respiratory tests: hyperventilation and breath-holding. The demonstrated changes in reactions of the respiratory system to functional breathing tests in the presence of hypoxia are indicative of the phasic dynamics of adaptation. The method used makes it possible to examine individual distinctions of respiratory regulation, which are attributable to the interaction of neurogenic and humoral factors, as well as differences in people's individual sensitivity to various humoral factors.

UDC: 612.273.2

"Mouse Resistance to Hypoxia Progressing at Different Rates," by V. V. Vlasov, I. P. Yunkin and V. I. Sovetov

Determination was made of the resistance of white mice, first to "mild" hypoxia and 3-5 days later to hypoxia that built up at a high speed. Resistance to hypoxia was determined by the duration of the period of defense and adaptive reactions. It was found that resistance to hypoxia, which was increased at an average [moderate] rate, was related to resistance to "mild" hypoxia. Resistance to "hard" and rapidly increasing hypoxia is inversely related to resistance to "soft" hypoxia. Increased resistance to "hard" hypoxia in animals with relatively low resistance to "soft" hypoxia had been demonstrated before: animals with low resistance to decompression survived for a longer time in the presence of a massive gas embolism. Animals with high resistance to "soft" hypoxia have a lower body weight, whereas resistance to "hard" hypoxia was directly related to body weight. The use of different parameters of the condition of an organism for predicting its resistance is limited to a specific range of values of the factor involved.

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